OM

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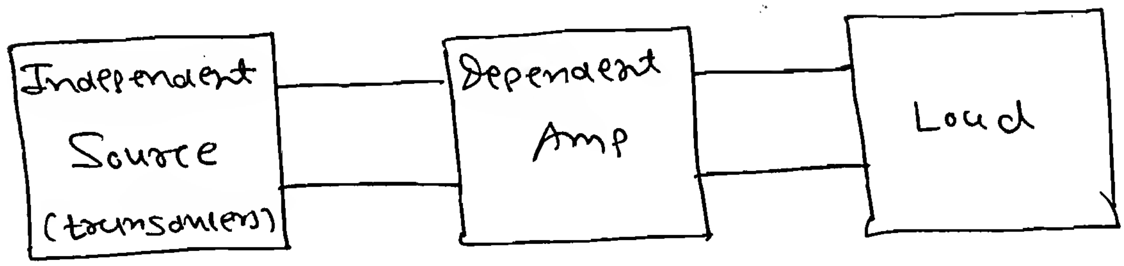
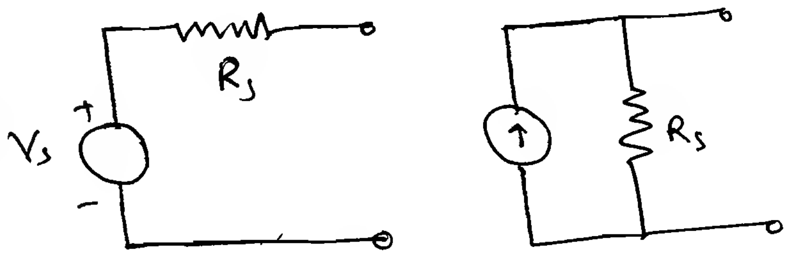
Analog Circuits.

✰ Amplifier Modeling:



→ microphone



* Voltage amp $V_o = kV_{in}$ [VCVS].

Current amp $I_o = kI_{in}$ [CCCS].

Transconduction amp $I_o = kV_{in}$ [VCCS].

TransResistance amp $V_o = kI_{in}$ [CCVS].

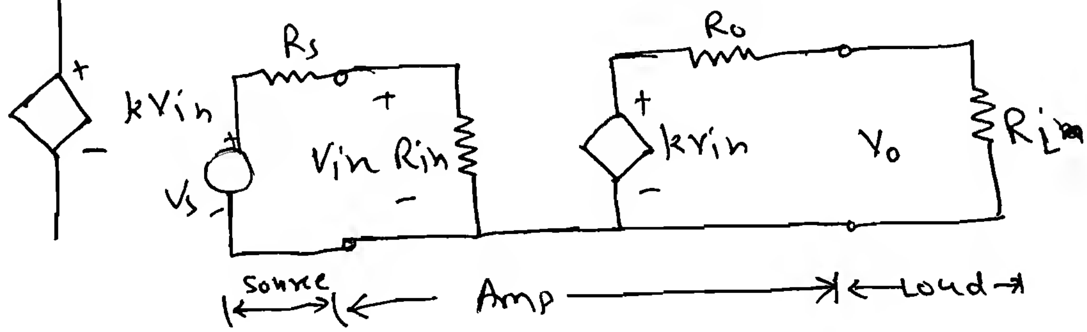
* Four Types of Amplifier:

(1) Voltage amplifier or

Voltage control voltage Source.

→ VCVS

$V_o = kv_{in}$ (V_o should be inde. of R_L).



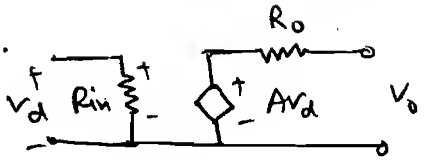
VC → $R_{in} = \infty$, $R_o = 0$. (Ideal).

$v_{in} = V_s$ $V_o = kv_{in}$

NOTE:

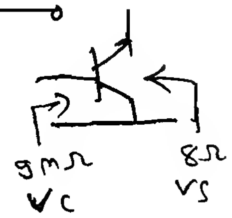
→ Amplifier is Unilateral amp. and doesn't violate Reciprocity theorem.

→ Eg: OPAM, CC amplifier

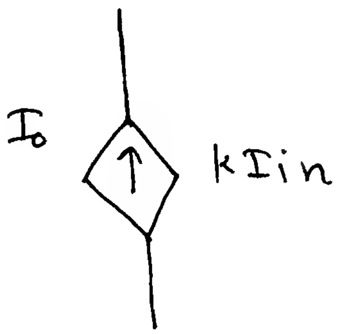


eg.1

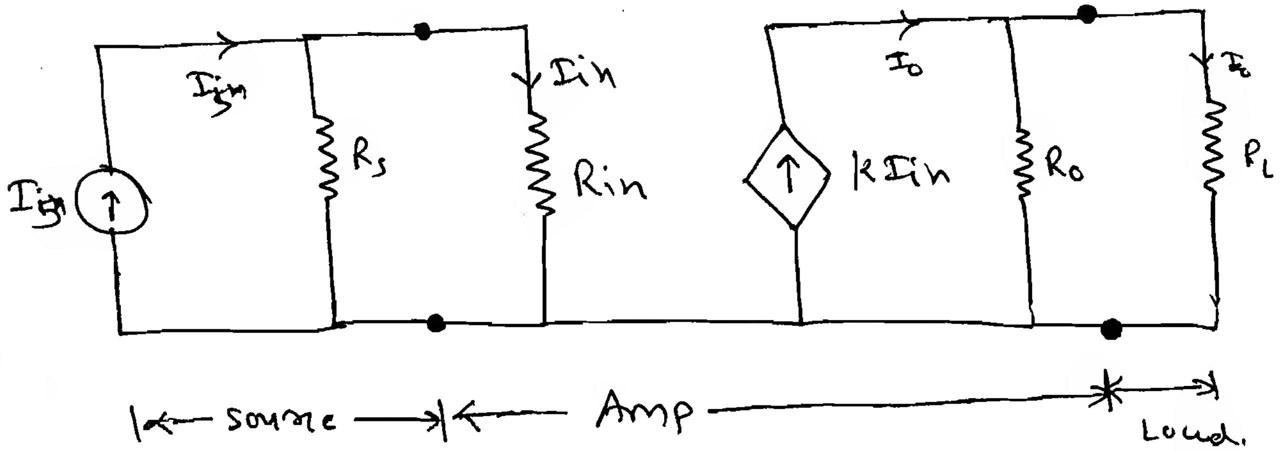
(2) Current amplifier or current control current source amplifier:



⇒



(I_o should be independent of Load)

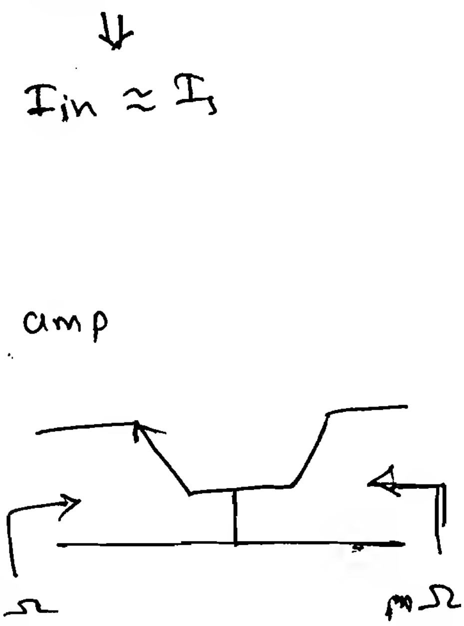


(CC) $R_{in} \approx 0$ ⇓ $I_{in} \approx I_s$

$R_o \approx \infty$ ⇓ $I_o = kI_{in}$. (CS)

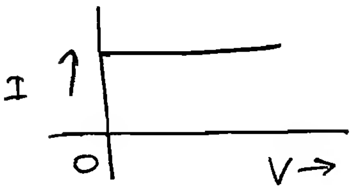
e.g.:

(1) CB amp

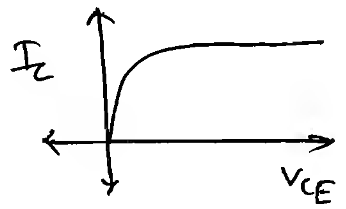


(CC) (CS)

* Characteristics of current source:



e.g. ② BJT



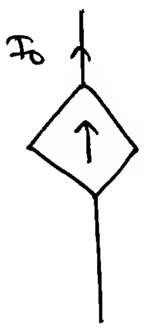
$$\Rightarrow R_o = \frac{1}{slop} = \frac{1}{0} = \infty.$$

So, BJT is current source.

(3) Voltage control current source Amp.

(OR) Transconductance Amp.

$\Rightarrow$

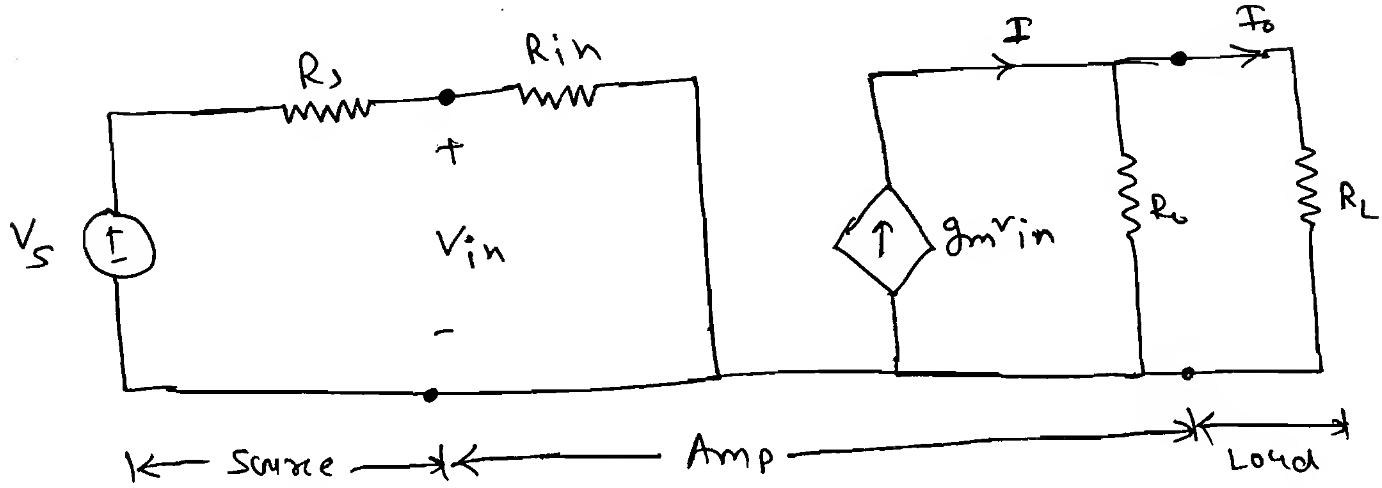


$kV_{in} = gV_{in}$

$$\boxed{g_m = \frac{I_o}{V_{in}}}$$

g_m → transconductance.

$\therefore I_o = g_m V_{in}.$



$\Rightarrow R_{in} \approx \infty$

$\Downarrow$

$V_{in} \approx V_s$

$\Downarrow$

voltage control

$R_o \approx \infty.$

$\Downarrow$

$I_o = g_m V_{in}$

$\Downarrow$

current source.

e.g.: ① FET, operational transconductance amp (OTA).

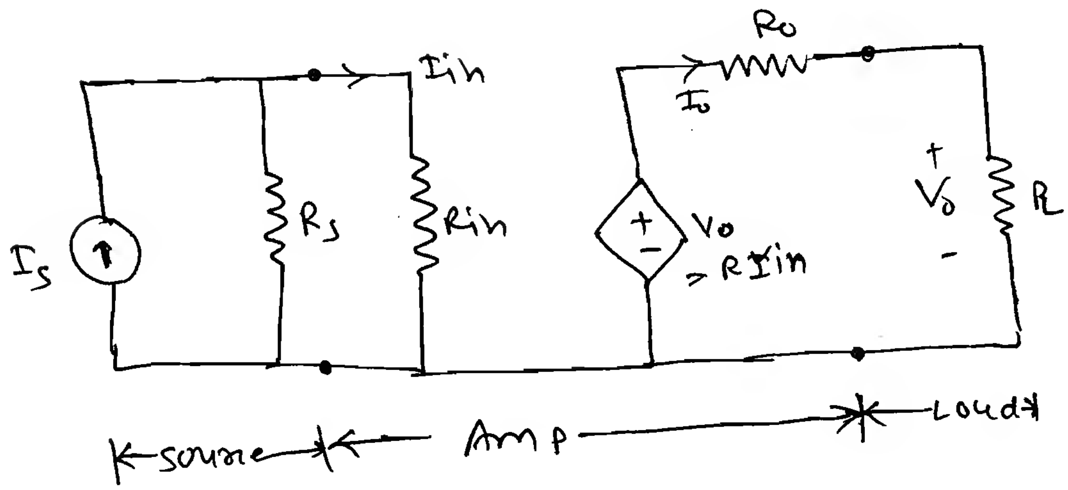
④ Current control Voltage Source:

(or) Transresistance amp.

$V_o = R_m I_{in}$

$\therefore \boxed{R_m = \dfrac{V_o}{I_{in}}}$

Trans Resistance



$R_{in} \approx 0$

$\Downarrow$

$\therefore I_{in} \approx I_s$

CC

$R_o \approx 0$

$\Downarrow$

$V_o = R_m I_{in}$

$\Downarrow$

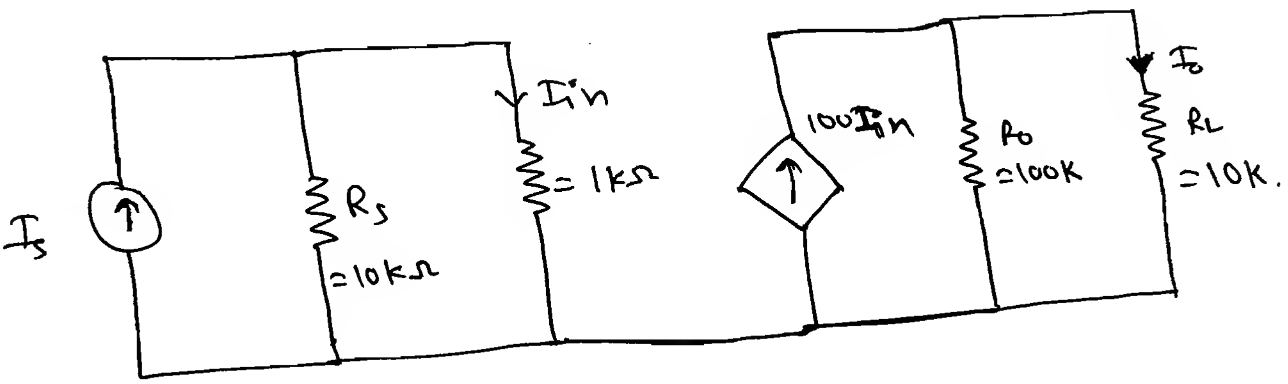
VS

* Summary

Amp	R_{in}	R_o		
1) Voltage	high	Low	$A_V = \frac{V_o}{V_{in}}$	(VSVC).
2) Current	Low	high	$A_I = \frac{I_o}{I_{in}}$	(CSCS).
3) Trans Conductance	high	High	$G_m = \frac{I_o}{V_{in}}$	(CSVC).
4) Trans Resistance	Low	Low	$R_m = \frac{V_o}{I_{in}}$	(VSCC).

Ex-1 Find Voltage gain, current gain and power gain of the current amplifier.

→



→ $I_o = \frac{100}{110} \times 100 I_{in}$.

$\therefore \frac{I_o}{I_{in}} = A_I = \frac{100 \times 100}{110}$.

$\therefore \cancel{A_I} = \frac{10^4}{110}$ *

$\therefore$ Now, $V_o = I_o \times 10k$.

$V_o = \frac{100}{110} \times 100 \times 10K \times I_{in}$.

$\therefore V_o = \frac{10^8}{110} \times I_{in}$.

$$\therefore \quad I_{in} = \frac{10k}{11k} \times I_s.$$

$$\therefore \quad I_s = \frac{1k}{11k} \times I_{in}.$$

$$\therefore \quad I_o = \frac{100 \times 100}{110} \times \frac{10}{11} I_s.$$

$$\therefore \quad \boxed{\frac{I_o}{I_s} = \frac{10^5}{110 \times 11}} = A_I.$$

$\therefore$ Current gain $A_I = \dfrac{10^5}{110 \times 11}$.

$\therefore$ Voltage gain $(A_V) = \dfrac{V_o}{V_s}$.

$$\therefore \quad V_s = 10k \times \frac{1k}{11k} \times I_{in}.$$

$$\therefore \quad V_s = \frac{10 \times 10^3}{11} \times \frac{110}{10^8} \cdot V_o.$$

$$\therefore \quad \boxed{\frac{V_o}{V_s} = A_V = \frac{10^4}{11 \times 110}.}$$

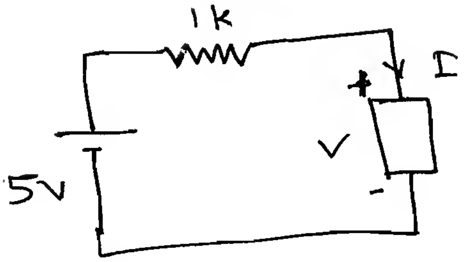
Power gain $(A_P) = A_V \times A_I$

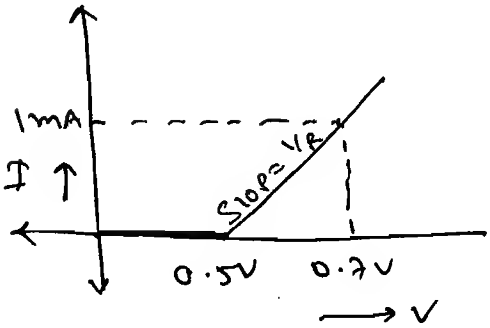
$$\therefore \quad \boxed{A_P = \frac{10^9}{(110)^2 \times (11)^2}.}$$

$\therefore$ Compounding means taking log.

$\therefore$ Gain db $= 10 \log A_P$.

Ex-1 Find I of the fig. If characteristics is given.





$\therefore R = \dfrac{0.2}{10^{-3}} = 200\,\Omega.$

$\therefore$ Slop $= I/V = \dfrac{1}{200}.$

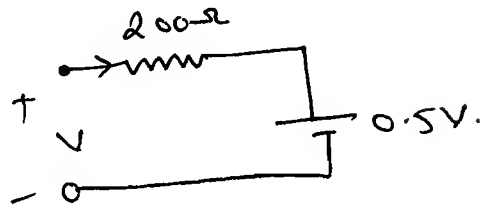
$\therefore$ Eq. $(0.5, 0)$ to $(0.7, 1m)$.

$\therefore \dfrac{y - y_1}{y_2 - y_1} = \dfrac{x - x_1}{x_2 - x_1}.$

$\therefore \dfrac{I - 0}{1m} = \dfrac{V - 0.5}{0.2}.$

$\therefore 200 I + 0.5 = V.$

$\therefore \boxed{V = 200 I + 0.5}$

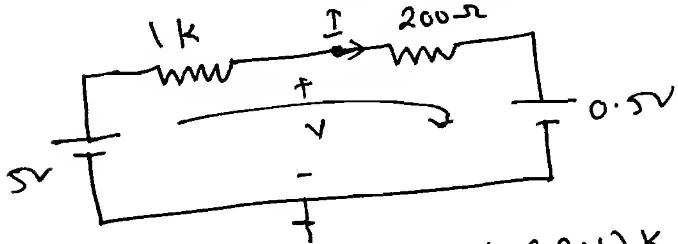


~~Now, V = 4.5 V.~~

~~So, ...~~

$\therefore$ ~~I = 4.5/250~~

So,



$\therefore 5 - 0.5 = I\,(201)\,k$

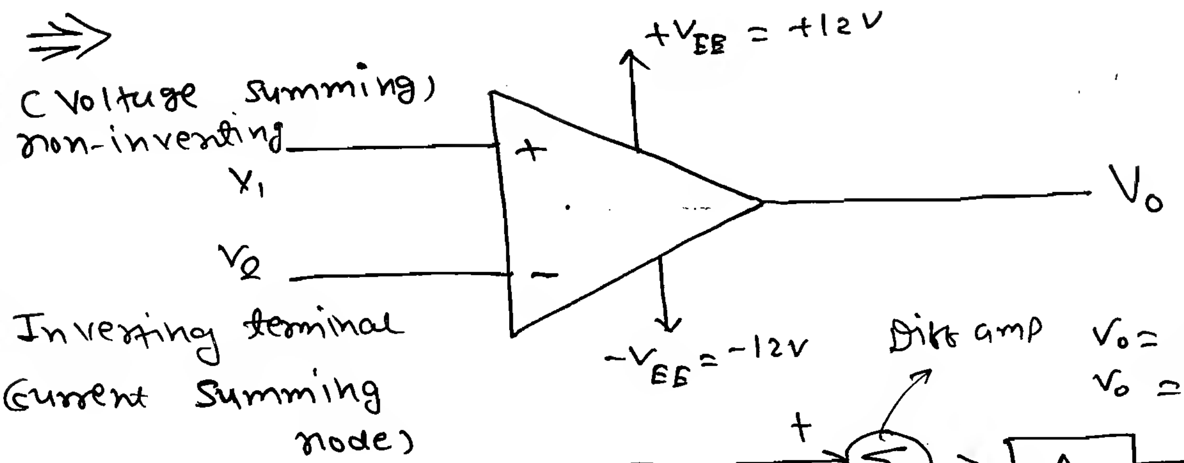
$\therefore \boxed{I = 3.75\ mA}$

$\therefore V = 200 \times 3.75 \times 10^{-3} + 0.5$

$\therefore V = 7.5 + 0.5 = 0.8\ V. \Rightarrow \boxed{V = \cancel{0.8V}}$ 1.25V

☆ Operational amplifier: (OP-Amp)

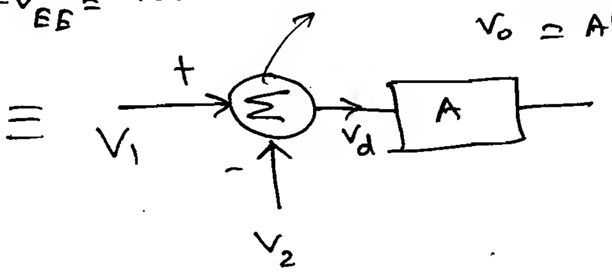
⟹



Diff amp $V_o = AV_d$

$V_o = A(V_1 - V_2)$

$\equiv$

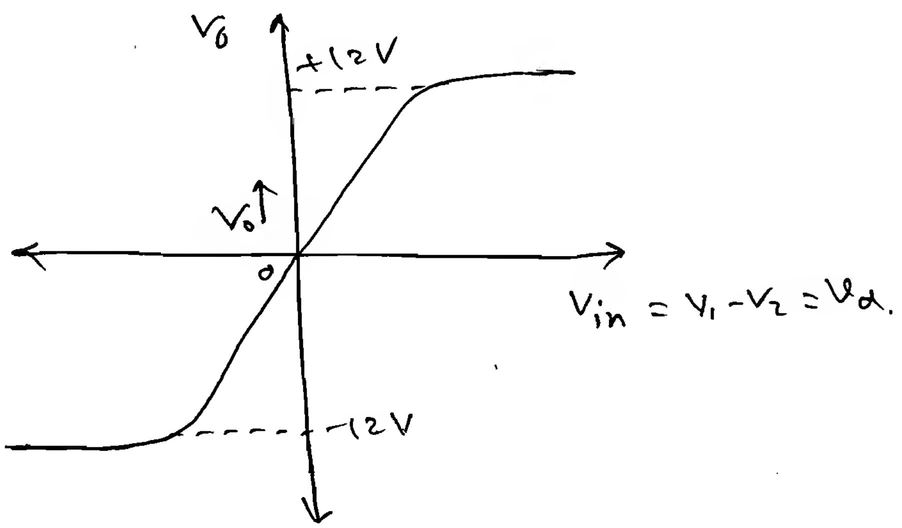


$$\therefore \quad V_o = A_{OL}(V_1 - V_2).$$

$A_{OL} =$ open loop gain $\rightarrow 10^6$ [μA741 Fairchild].

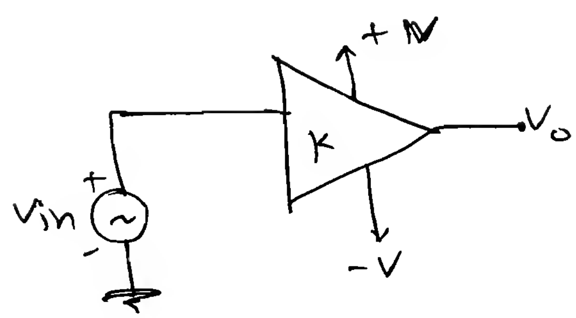
→ OP-Amp is a high gain differential Amplifier.

* Transfer characteristics:



NOTE: If an amplifier works with two supplies +V and −V with a gain K in order to avoid clipping the input signal swing

Should $-\frac{V}{K}$ to $+\frac{V}{K}$.



$-V \le V_o \le +V$.

$-\frac{V}{K} \le V_{in} \le +V/K$.

* Three Basic Modes of Operation of an Op-Amp:

(1) Negative feedback:

* **Linear** / **Nonlinear**

Linear	Nonlinear
VCVS } Amp	Rectifier
CCCS } Amp	peak Detector
VCCS } Amp	Clipper
CCVS	clampper
Adder	Log amp
subtracter	exp amp.
Instrumentation Amp	

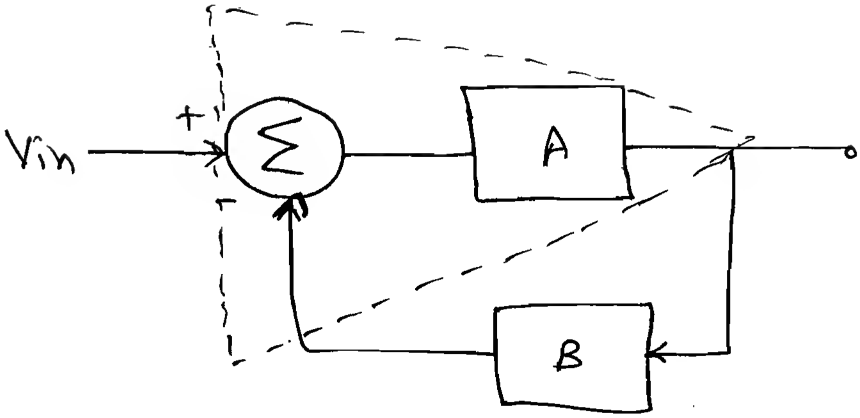
* Open loop	~~Crossed~~ positive feedback
Comparator (Detector)	schmit trigger → multivibrators.

MImp II

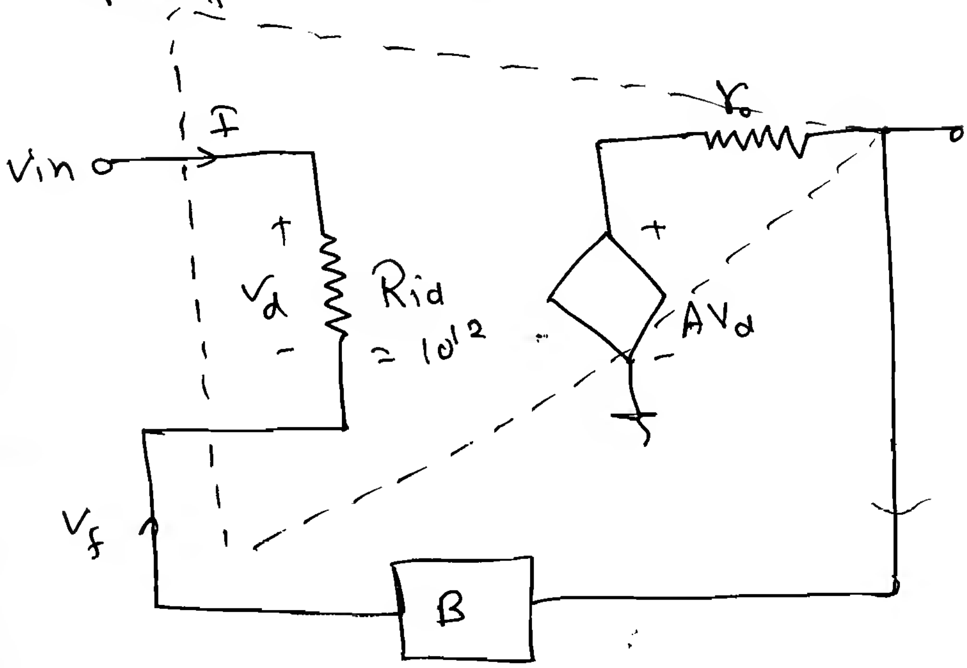
→ In order to solve circuits involving -ve feedback two realistic assumptions are made.

① $V_{noninverting} = V_{inverting}$.

② op-amp draws no current.

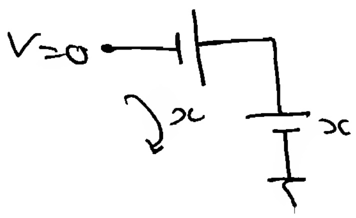


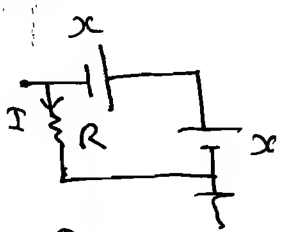
→ OP-Amp is VCVS.



$V_d = \frac{V_o}{A} = \frac{10}{10^6} = 10^{-5}$

* OP-Amp is nullator.



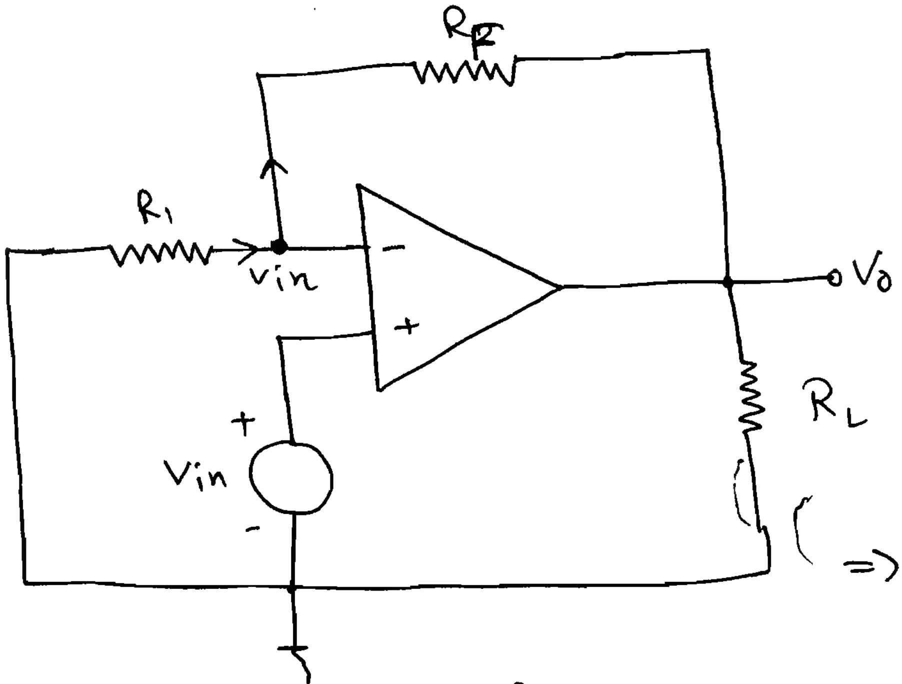


I=0.

So, V=0 & I=0.

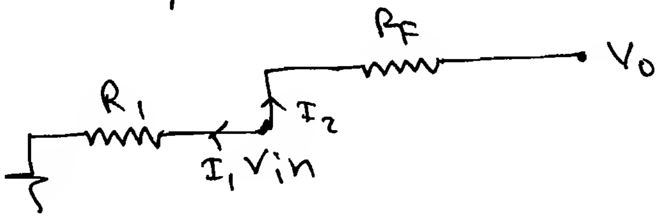
(1) Voltage Amplifier (or) Non-Inverting Amplifier (or) Voltage Control Voltage Source Amplifier).

*



⇒ VCVS

⇒



KCL $\quad I_1 = I_2$.

$$\therefore \frac{V_{in} - 0}{R_1} + \frac{V_{in} - V_o}{R_F} = 0$$

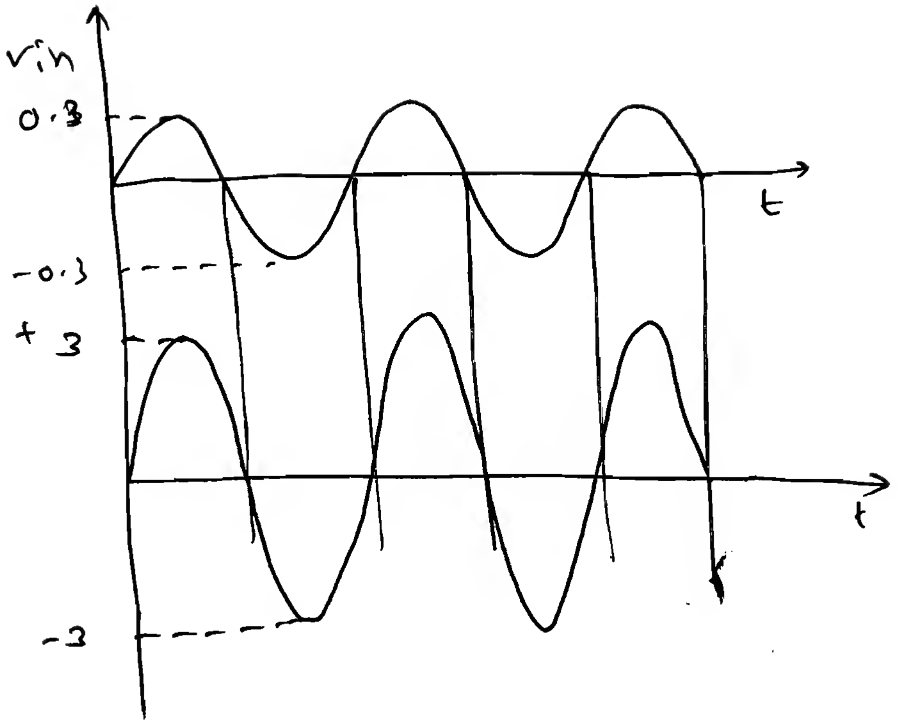
$$\therefore V_o = \left(1 + \frac{R_F}{R_1}\right) V_{in}$$

$$\therefore \boxed{V_o = K V_{in}.}$$

e.g. $\quad V_{in} = 0.3 \sin t, \quad R_F = 9K, \quad R = 1K.$

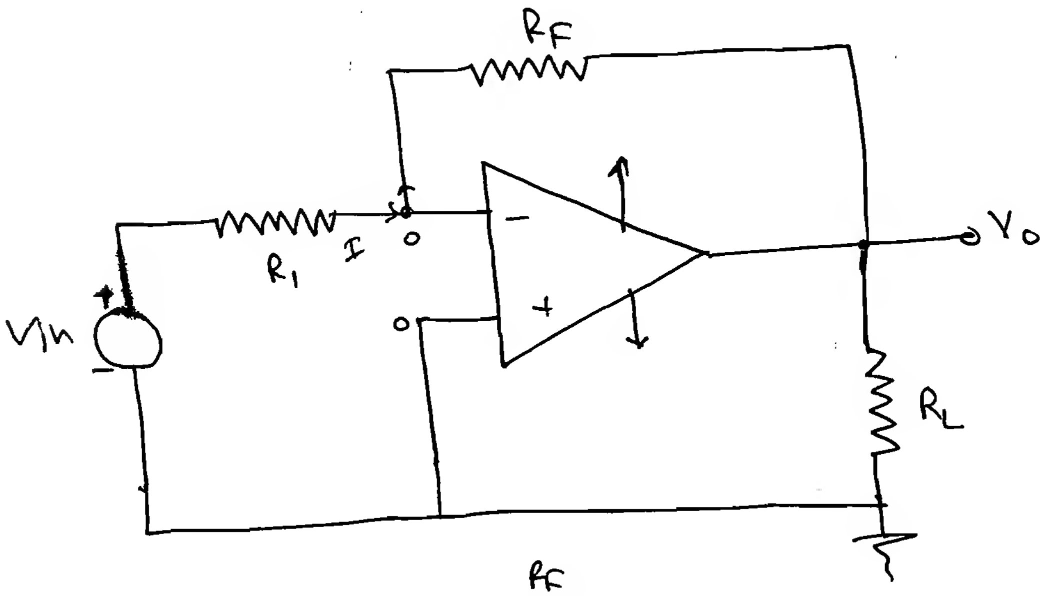
$$\therefore V_o = \left(1 + \frac{9}{1}\right) V_{in}$$

$$\therefore V_o = 10 V_{in} = 3 \sin t.$$



(2) Inverting Amplifier (or) Current Control Voltage Source (or) Trans Resistance Amplifier

⇒



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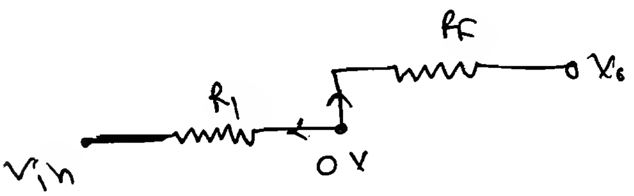


KCL $\dfrac{0 - V_{in}}{R_1} + \dfrac{0 - V_o}{R_F} = 0$

$$\therefore \boxed{V_o = \left(-\frac{R_F}{R_1}\right) V_{in}.}$$

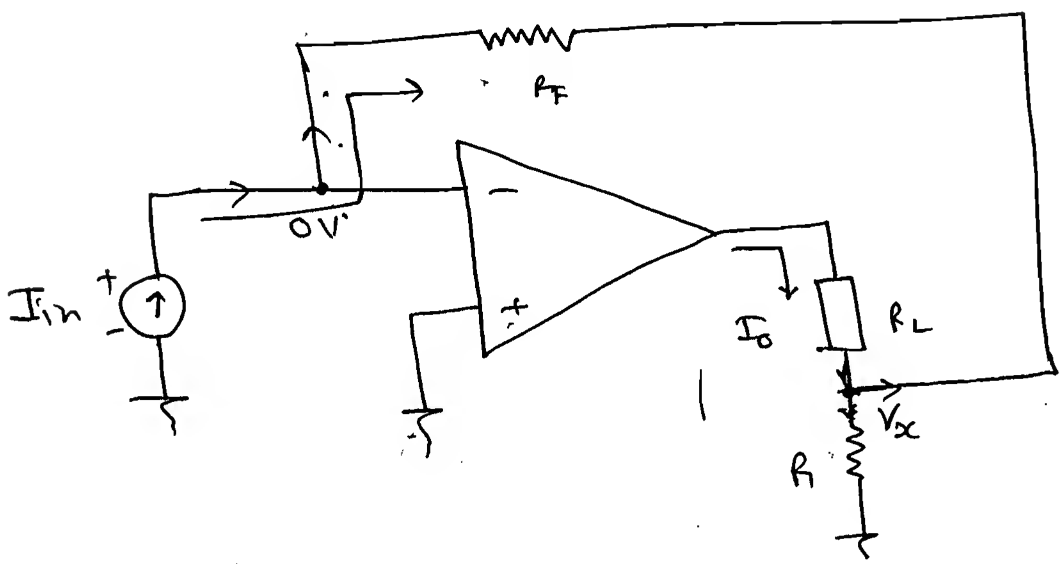
$$\rightarrow \quad V_o = (-R_F)\left(\frac{V_{in}}{R_1}\right) \rightarrow$$ current ~~source~~ control.

$$\therefore \quad V_o = -R_F \, I_{in}.$$

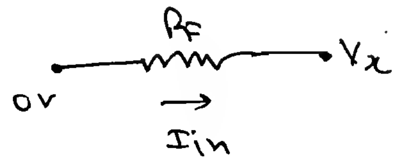
$\therefore$ Trans Resistance $\quad R_m = \dfrac{V_o}{V_{in}}.$

$$\therefore \quad \boxed{R_m \doteq -R_F.}$$

(3) Current Amplifier (OR) Current Control Current Source:



KCL: $\quad I_o = \dfrac{V_x}{R_1} + \dfrac{V_x - 0}{R_F}.$



$$\therefore \quad I_o = V_x\left[\frac{1}{R_1} + \frac{1}{R_F}\right] \quad -(1)$$

$$\therefore \quad I_{in} = \frac{0 - V_x}{R_F}.$$

$$\therefore \quad V_x = (-R_F)\, I_{in}. \quad -(2)$$

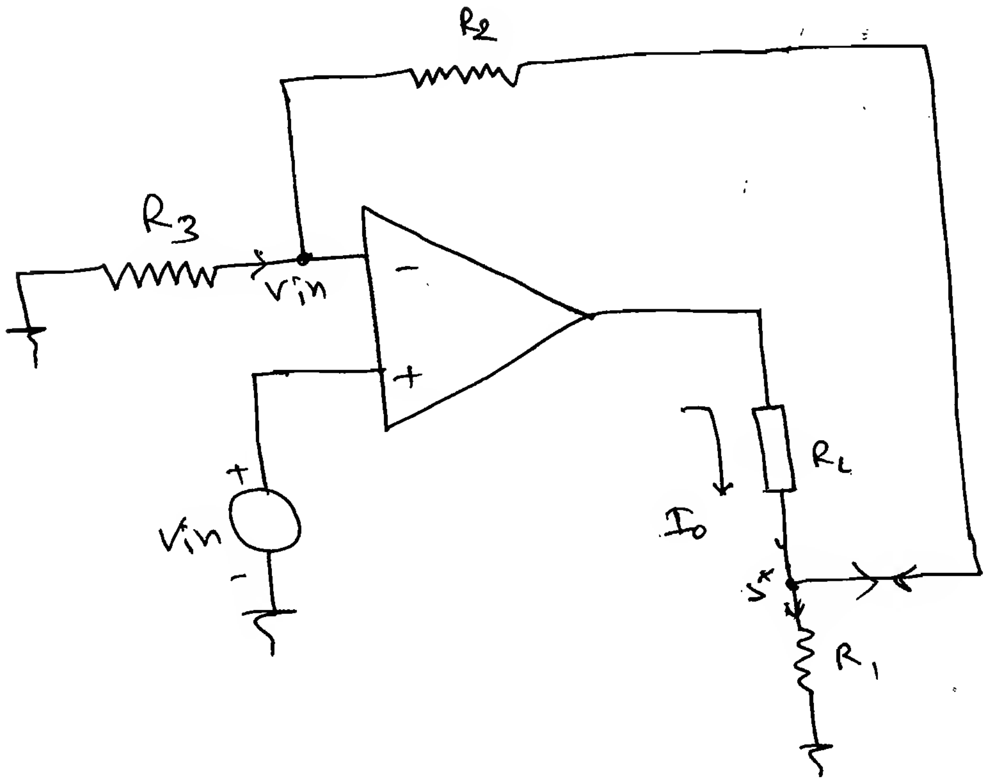
Sub (2) in (1)

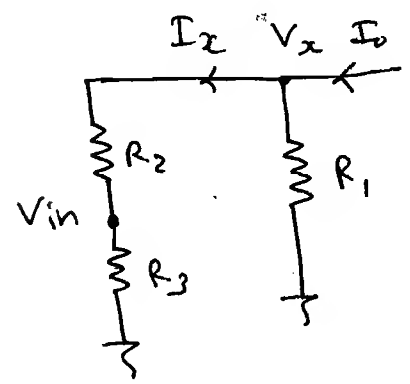
$$I_o = -R_F \, I_{in}\left[\frac{1}{R_1} + \frac{1}{R_F}\right].$$

$$\therefore \quad I_o = -\left[1 + \frac{R_F}{R_1}\right] I_{in} \Rightarrow \quad \boxed{I_o = k \, I_{in}.}$$

(4) Trans conductance Amplifiers (OR) Voltage Control ~~Volt~~ Current Source.

→





$$\therefore \quad I_x = \frac{R_1}{R_1+R_2+R_3} I_o.$$

$$\therefore \quad V_{in} = I_x \cdot R_3.$$

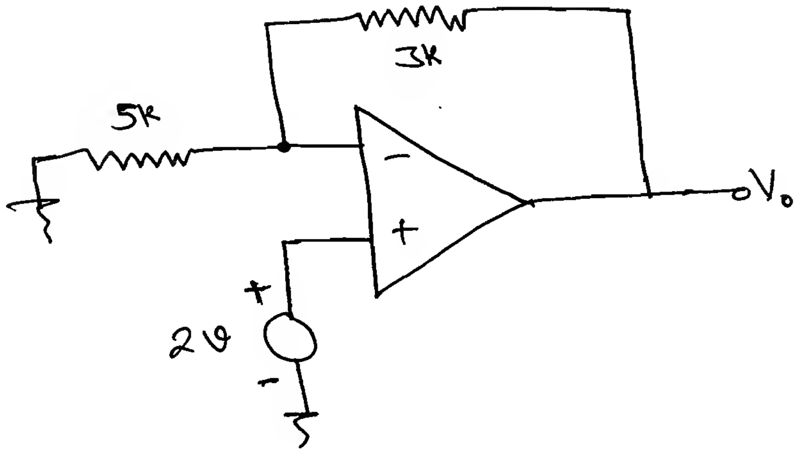
$$\therefore \quad V_{in} = \frac{I_o R_1 \cdot R_3}{R_1+R_2+R_3}$$

$\therefore$ transconductance

$$\boxed{g_m = \frac{R_1+R_2+R_3}{R_1 R_3}.}$$

Ex-1 Find the o/p Voltage if op-Amp is Consider ideal.

(1)

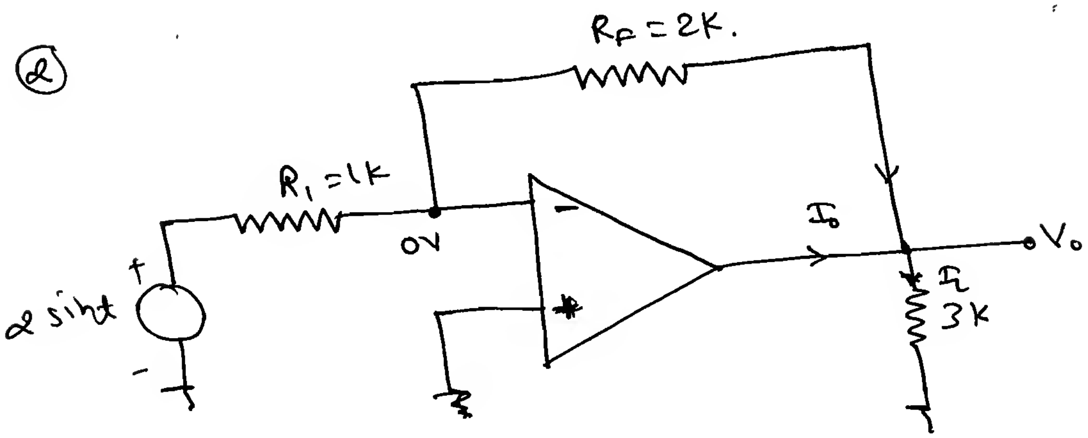


$\therefore \quad V_o = \left(1 + \frac{R_F}{R_1}\right) V_{in}.$

$\therefore \quad V_o = \left(1 + \frac{3}{5}\right) 2V.$

$\therefore \quad \boxed{V_o = \frac{16}{5}\ V}$

(2)



$\therefore \quad V_o = -\frac{R_F}{R_1} . V_{in}.$

$\therefore \quad V_o = -4\sin t.$

$I_o + I_F = I_L.$

$\therefore \quad I_o = I_L - I_F.$

$= \frac{V_o}{3} - \frac{[0 - V_o]}{2k}$

$= \cancel{\frac{-4\sin t}{3} + \frac{4\sin t}{3}}$

$\therefore \quad \boxed{I_o = \cancel{\frac{-8\sin t}{3}}\ A.}$

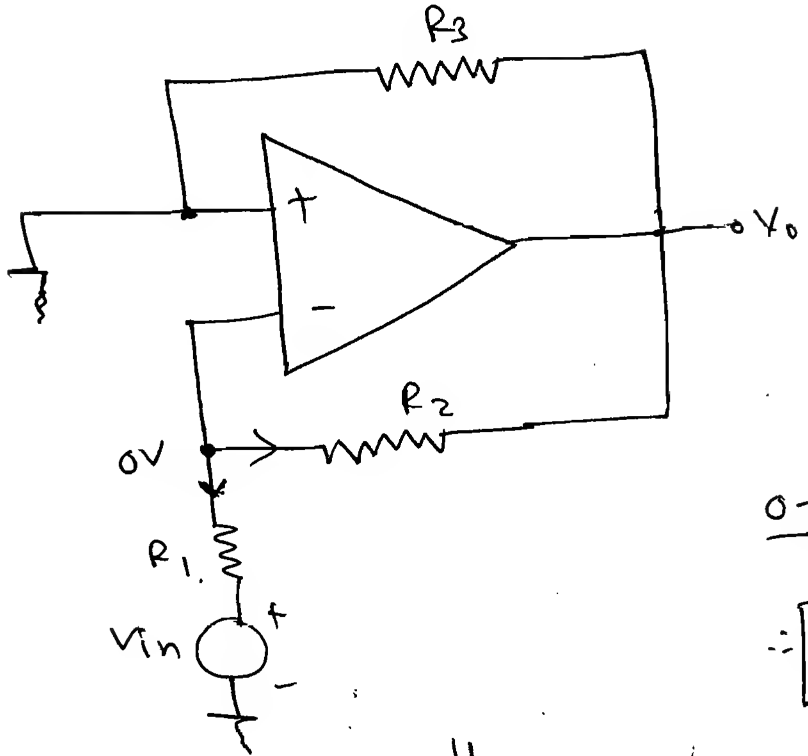
$$I_o = \frac{V_o}{3K} + \frac{V_o}{2K}$$

$$= \frac{5V_o}{6K}$$

$$I_o = \frac{5(-\cancel{4}^{2}\sin t)}{\cancel{6}_{3}K}$$

$$\therefore \boxed{I_o = -\frac{10}{3}\sin t \text{ mA}}$$

Ex- 3

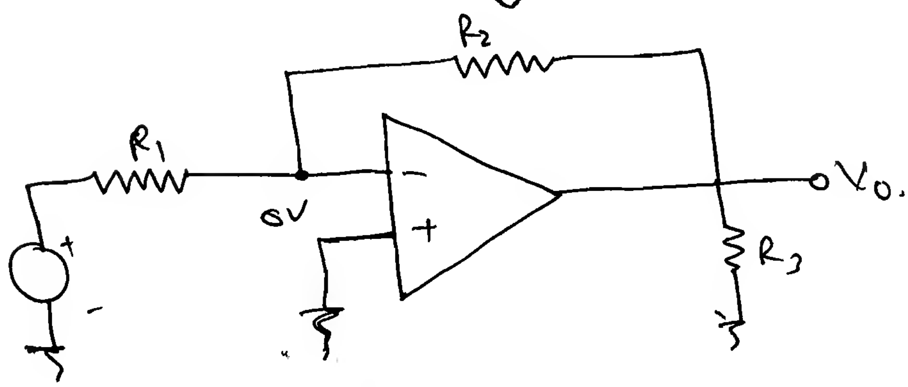


KCL

$$\frac{0 - v_{in}}{R_1} + \frac{0 - V_o}{R_2} = 0$$

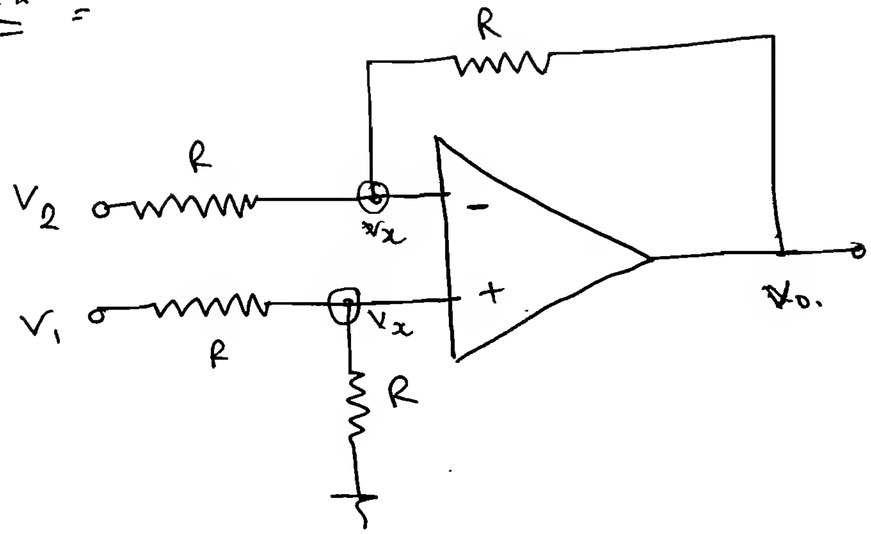
$$\therefore \boxed{V_o = -\left(\frac{R_2}{R_1}\right) v_{in}.}$$

⇓



$$\therefore \quad V_o = -\left(\frac{R_2}{R_1}\right) v_{in}.$$

Ex 4



→ By supperposition theorem

① Let $V_2 = 0$; & V_1 is given.

$$\therefore V_x = \frac{R}{R+R} \cdot V_1$$

$$\therefore V_x = V_1/2.$$

$$\therefore V_{o1} = \left(1 + \frac{R}{R}\right) \frac{V_1}{2}.$$

$$V_{o1} = V_1$$

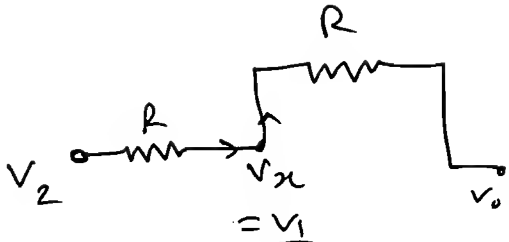
② Let $V_2 = V$ and $V_1 = 0$.

$$\therefore V_{o2} = \left(-\frac{R}{R}\right) V_2.$$

$$\therefore V_{o2} = -V_2.$$

$$\therefore V_o = V_{o1} + V_{o2}.$$

$$\therefore \boxed{V_o = V_1 - V_2 . \ V}$$



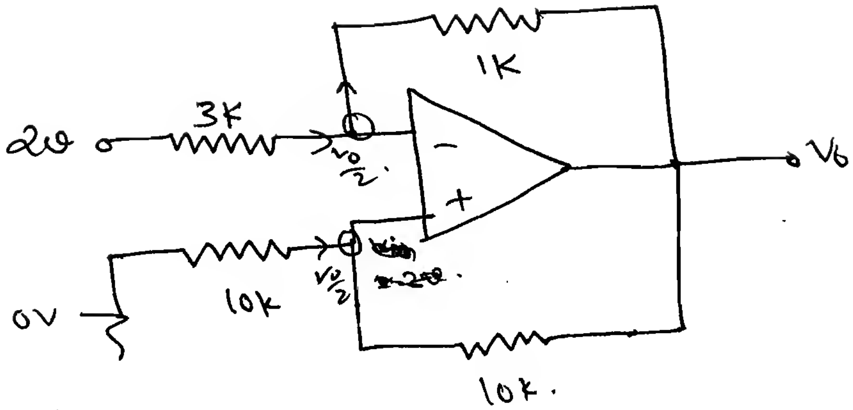
$$\therefore \frac{V_2 - \frac{V_1}{2}}{R} = \frac{\frac{V_1}{2} - V_o}{R}$$

$$\therefore V_2 - V_1 = -V_o$$

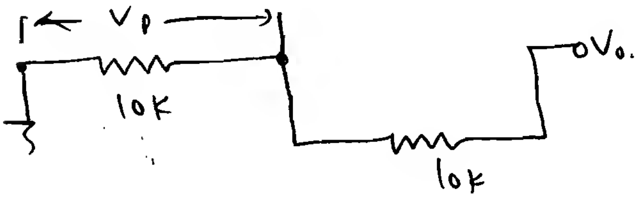
$$\therefore \boxed{V_o = V_1 - V_2}$$

Subtractor.

Ex-5



→



$\therefore \quad V_p = \frac{V_0}{2}$

$\therefore \quad \frac{2 - \frac{V_0}{2}}{3} = \frac{\frac{V_0}{2} - V_0}{1}$

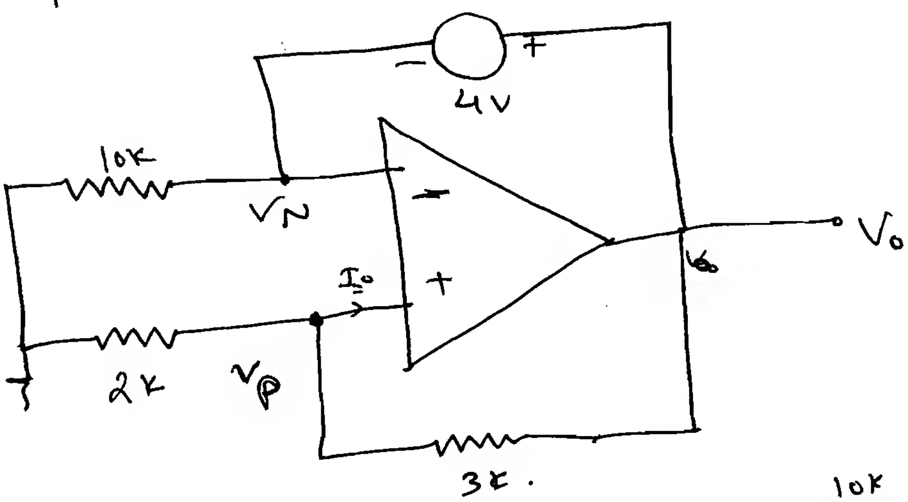
$\therefore \quad \frac{4 - V_0}{\cancel{6}\,3} = -\frac{V_0}{\cancel{2}}$

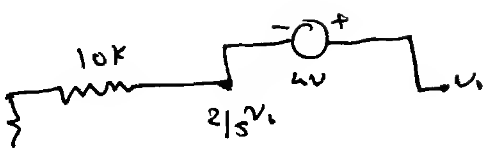
$\therefore \quad 4 - V_0 = -3V_0$

$2V_0 = -4$

$\boxed{V_0 = -2\,v}$

Ex-6 Find V_p, V_n & V_0.





$\therefore \quad V_p = \frac{2}{5} \times V_0$

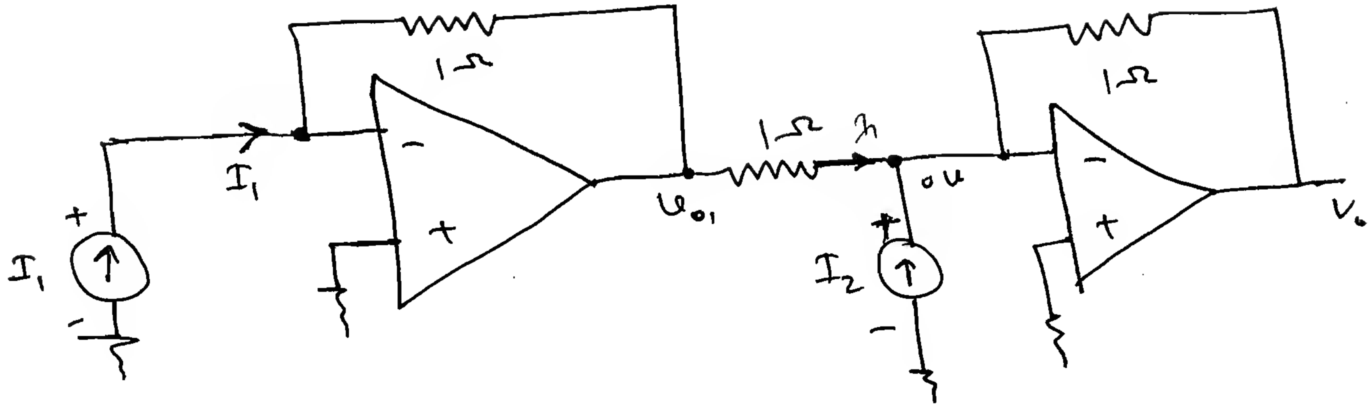
$\therefore \quad \boxed{V_N = V_P = \frac{2}{5} \times V_0}$

$\therefore \quad V_0 - 2/5\,V_0 = 4\,V$

$\frac{3}{5} V_0 = 4$

$\therefore \quad \boxed{V_0 = 20/3\,V}$

Ex-6 Find V_o in terms I_1 & I_2.



$\therefore \quad v_{o1} = -1(I_1)$

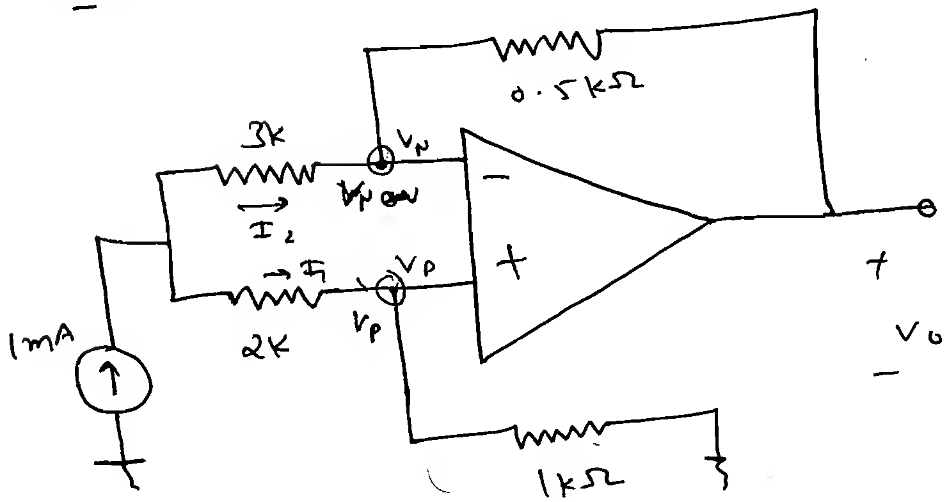
$$\boxed{v_{o1} = -I_1}$$

$$\therefore \quad \frac{v_{o1} - 0}{1} + I_2 = \frac{0 - v_o}{1}.$$

$\therefore \quad -I_1 + I_2 = -v_o$

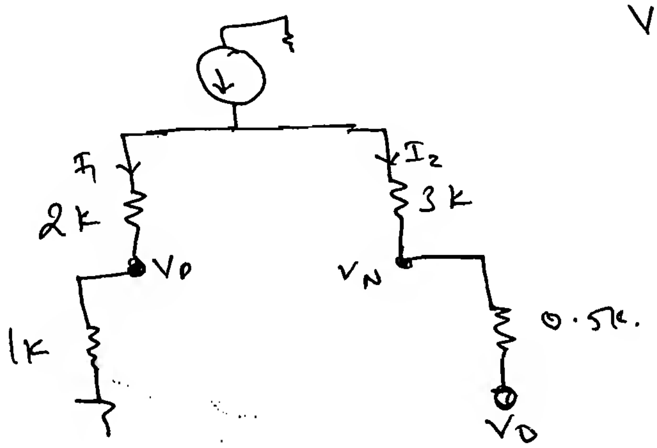
$$\therefore \quad \boxed{v_o = I_1 - I_2.}$$

Ex-8



$V_P = V_N.$

$\therefore$



$$I_1 = \frac{1m(3k)}{2k+3k} = 0.6 mA$$

$$\therefore \quad I_2 = I - I_1$$

$$\boxed{I_2 = 0.4 mA}$$

$$\therefore \quad V_p = I_1 \times 1k$$

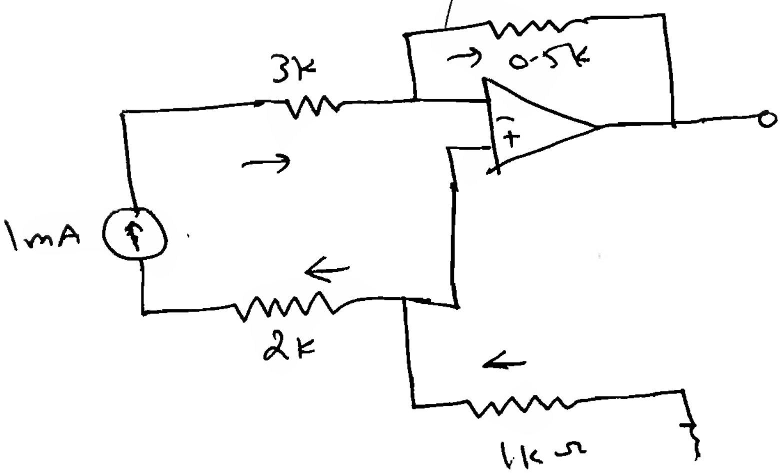
$$\boxed{V_p = 0.6 V.}$$

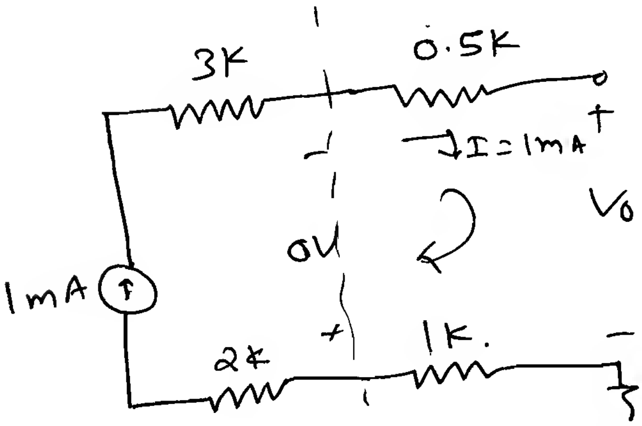
$$\therefore \quad I_2 = \frac{V_N - V_0}{0.5k}$$

$$\therefore \quad 0.4m = \frac{0.6 - V_0}{0.5k}.$$

$$\therefore \quad V_0 = -0.2 + 0.6$$

$$\boxed{V_0 = +0.4 V}$$

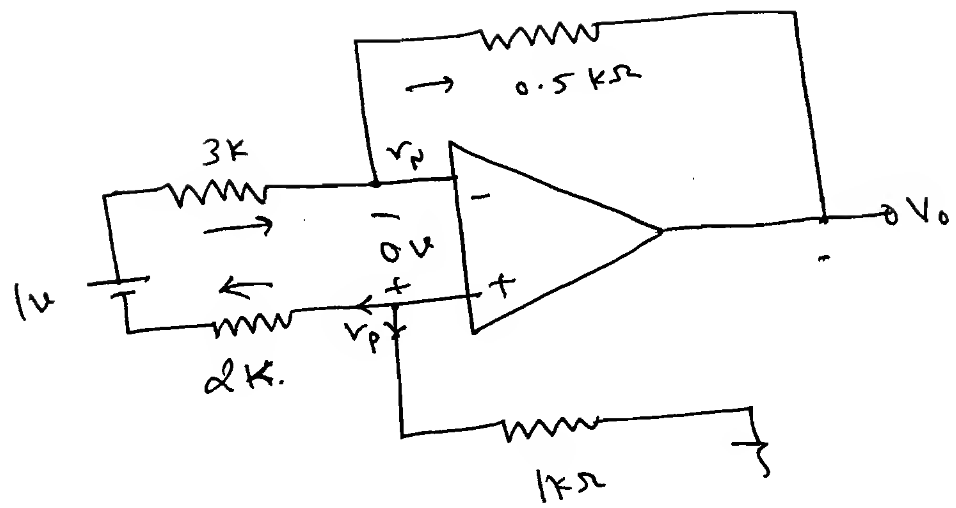




$$0 + I(0.5k) + V_0 + I(1k) = 0$$

$$\therefore \quad V_0 = -I(1.5k).$$

$$\boxed{V_0 = -1.5 V}$$



$\therefore -1 + I(3k) - 0 + I(2k) = 0.$

$\therefore \boxed{I = 0.2\ mA}$

$V_P =$

$\therefore V_P = (-1k)(0.2).,$

$\boxed{V_P = -0.2V.}$

$I + \frac{V_P}{1k} = 0$

$V_P = (-I)(1k).$

$V_P = (0.2m)(-1k).$

$\boxed{V_P = -0.2V}$

$\therefore \boxed{V_N = -0.2V.}$

$\therefore I = \frac{V_N - V_o}{0.5k}.$

$\therefore 0.2m = \frac{-0.2 - V_o}{0.5}$

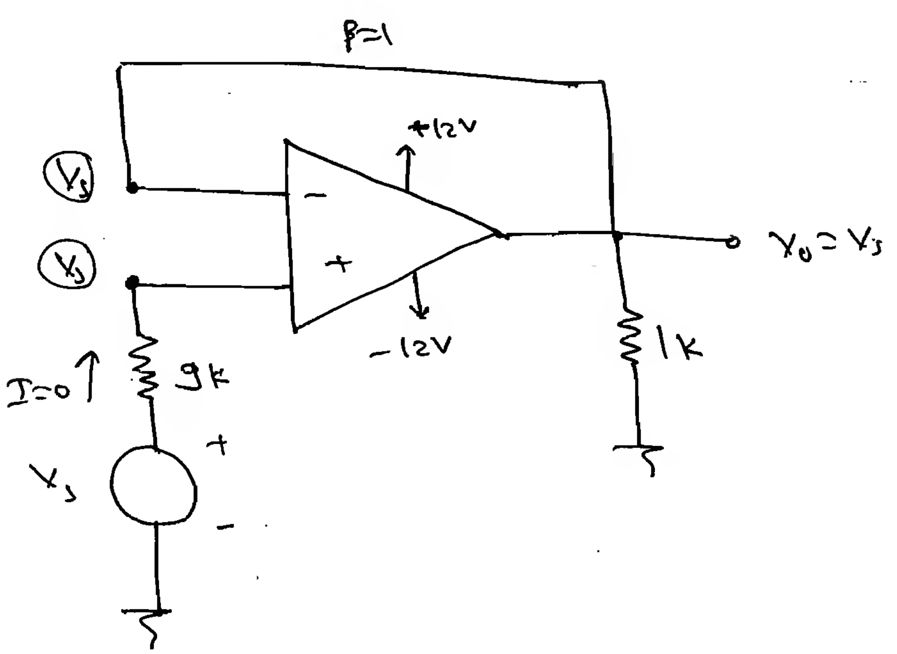
$-0.1 + 0.2 = V_o$

$\therefore \boxed{\cancel{V_o = -0.8V}}$

$\therefore \boxed{V_o = -0.3V.}$

* Buffer (or) Voltage follower (or) Unity gain amplifier.

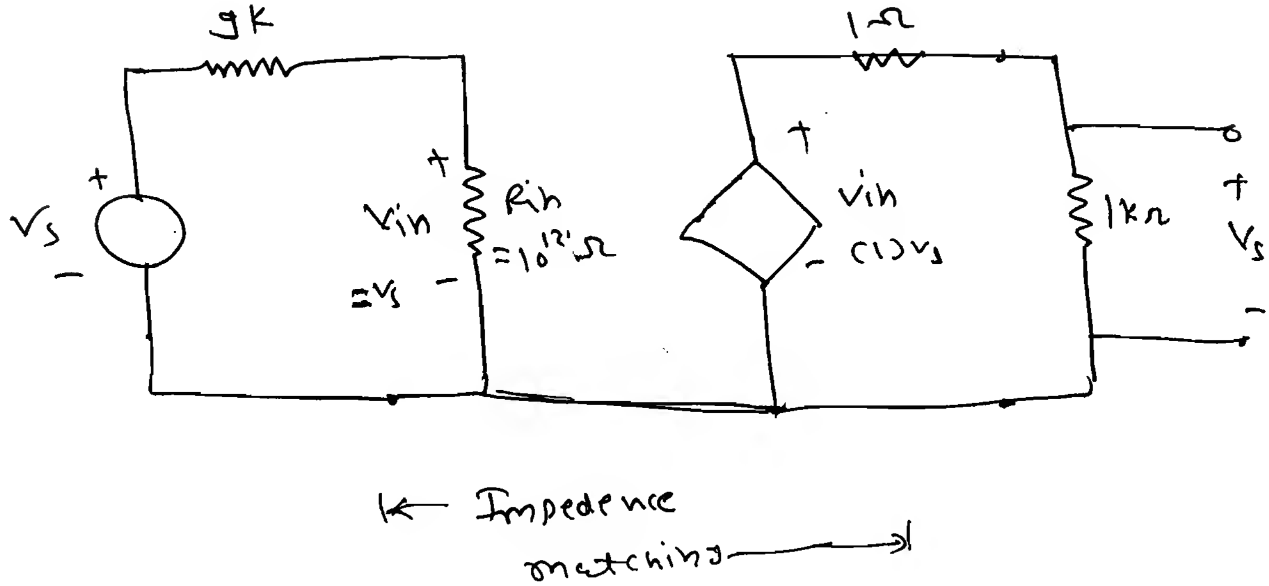
→ Impedence matching device is device which connect high impedence source to Low impedence Load.



→ $A_f = \dfrac{A}{1+A\beta} = \dfrac{10^6}{1+10^6(1)} \approx 1.$

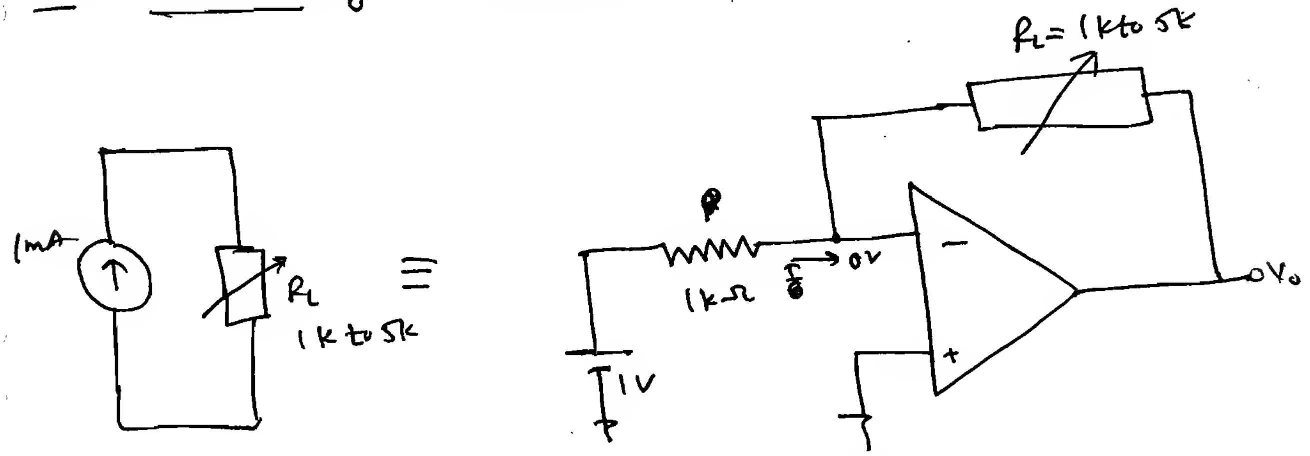
∴ $\boxed{A_f = 1.}$

→

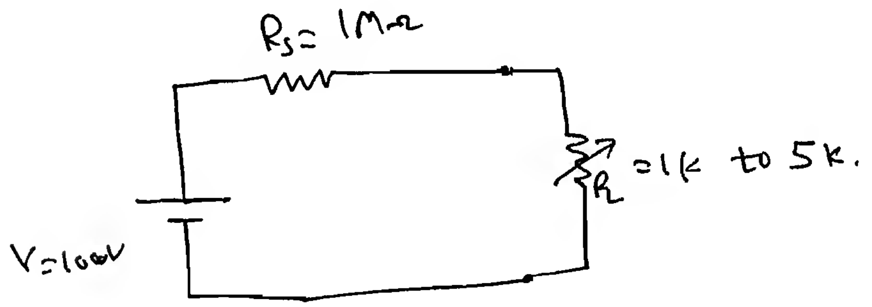


Voltage Buffer	Current Buffer
High R_{in}	Low R_{in}
Low R_o	High R_o
$A_V \simeq 1$	$A_I \simeq 1$
High A_I	High A_V
$A_P = A_V A_I$	$A_P = A_V A_I$
$A_P = A_I$	$A_P = A_V$.
e.g. Common Collector.	e.g: Common Base.

* Building Current Sources:



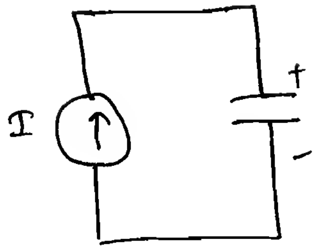
I = 1mA.



$R_s \gg R_L$

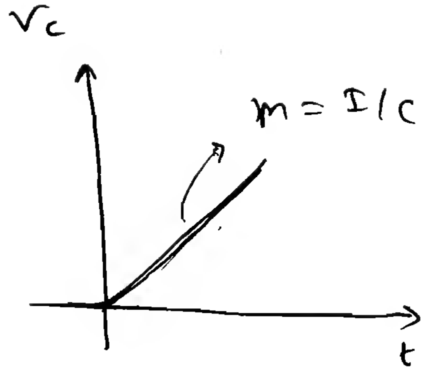
* Miller Integrator:

*



$V_c = \frac{1}{C}\int I\,dt$

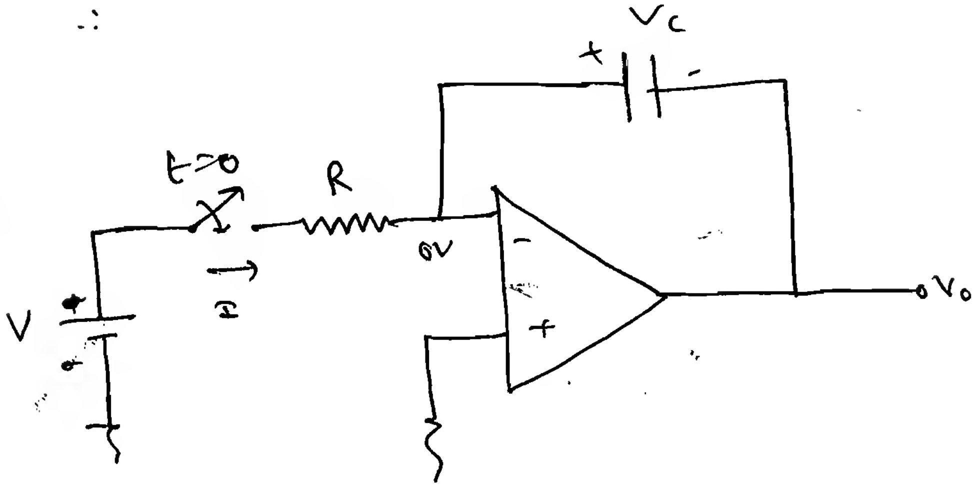
$V_c = \left(\frac{I}{C}\right)\int dt$



$\therefore V_c = \left(\frac{I}{C}\right) t$ $\Rightarrow$ $y = V_c$

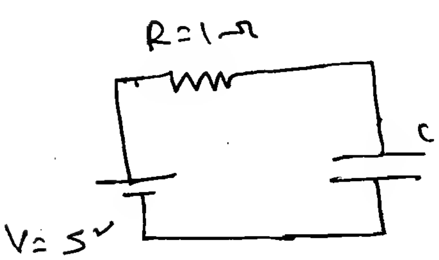
$\therefore y = mx + C.$ $x = t$

$\therefore$

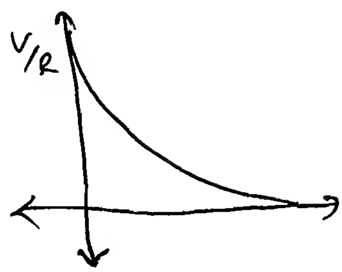


$I = V/R.$ const.

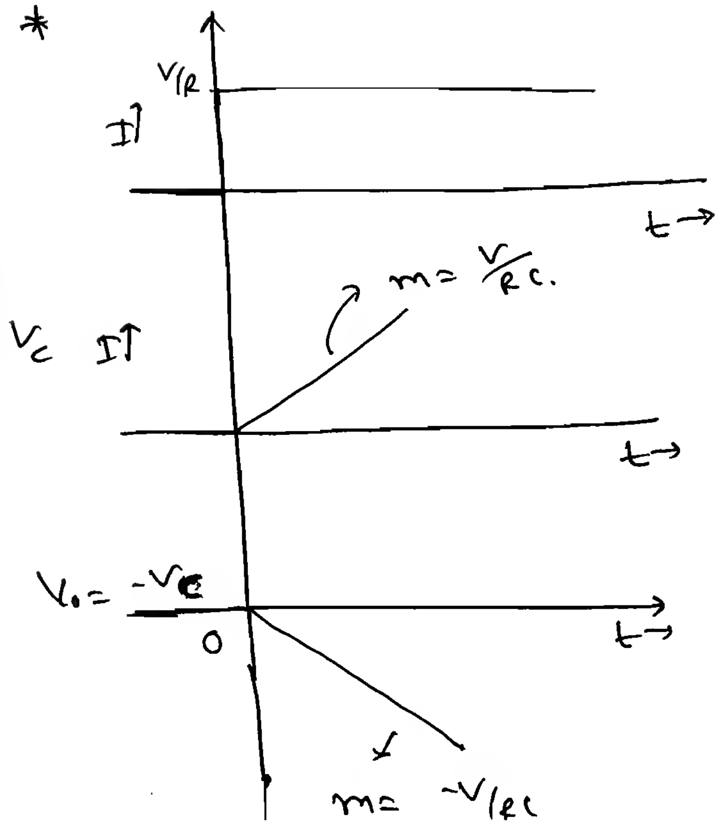
$\therefore V_c = \frac{1}{C}\int I\,dt = \left(\frac{I}{C}\right)t = \left(\frac{V}{RC}\right)t.$



V_c	$I = \frac{5-V_c}{1}$
0V	5A
1V	4A
3V	2A
5V	0A

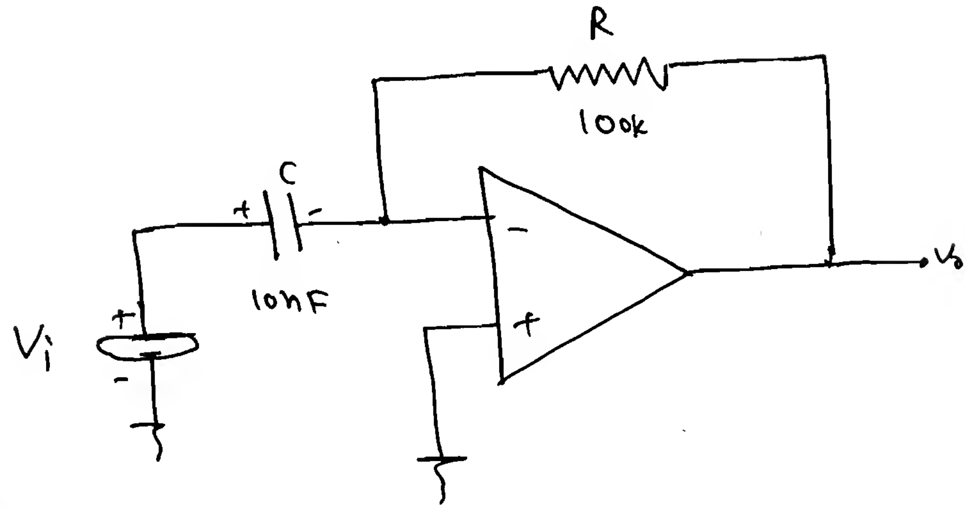


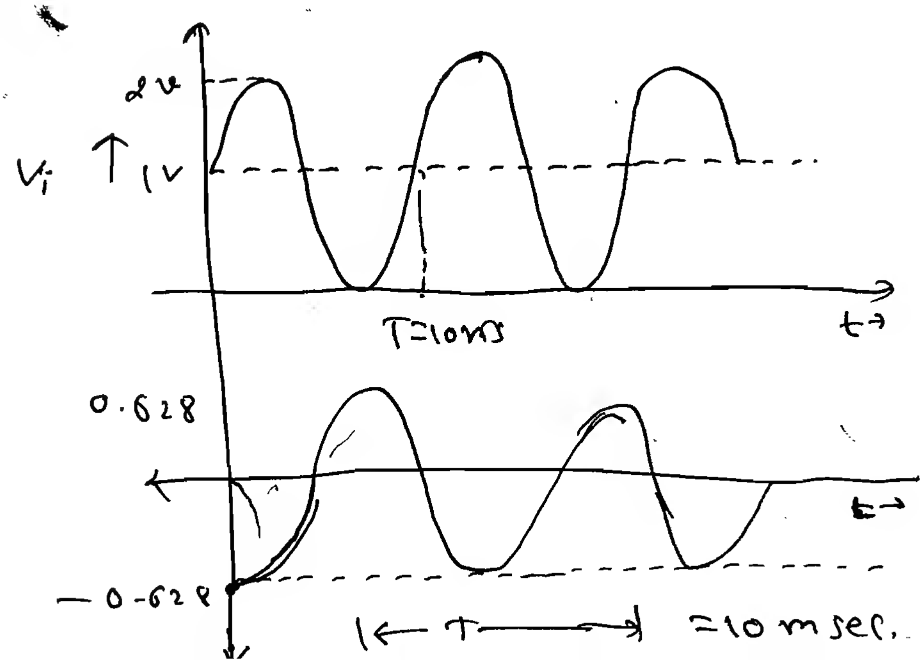
*



* Differentiator:

⇒





$$\frac{V_0}{V_{in}} = \frac{-R_F}{R_1}$$

$$\frac{V_0}{V_{in}} = \frac{-R_F}{(1/SC)} = -(RC)S$$

$$\boxed{V_0 = (-RC)\frac{dV_i}{dt}}$$

$\therefore \quad V_i = V_{DC} + V_m \sin \omega t$

$\therefore \quad V_i = 1 + 1 \sin \frac{2\pi}{T} t$

$V_i = 1 + \sin \frac{2\pi}{10ms} t.$

$$\boxed{V_i = 1 + \sin 200\pi t}$$

$\therefore \quad V_o = (-RC) \cdot \frac{dV_i}{dt}.$

$= \left(-100 \times 10^{+3} \times 10^{-8}\right) \times \cos 200\pi t \; (200\pi)$

$\therefore \quad V_o = -0.628 \cos 200\pi t.$

$t = 0$

$\therefore V_o = -0.628.$

$\therefore$

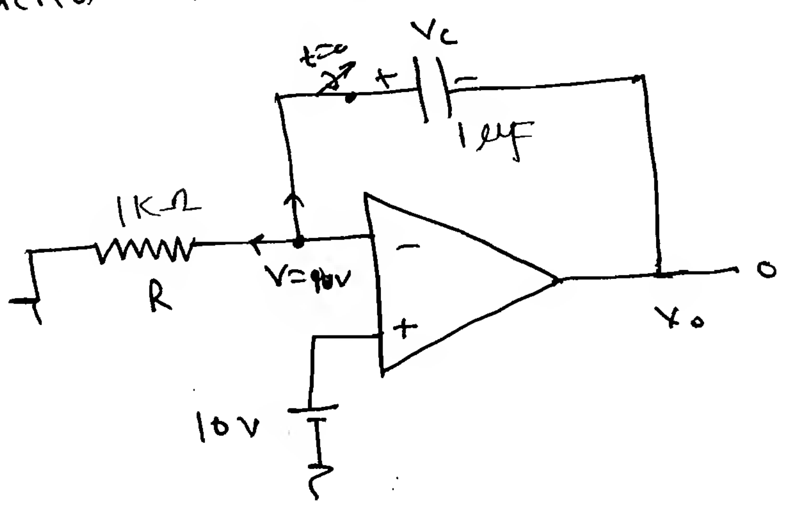
$\cancel{2\pi f t} = \cancel{200\pi t}$

$2f = \cancel{200}\,00$

$\therefore \quad T = 10^{-2}$

$$\boxed{T = 10\,ms.}$$

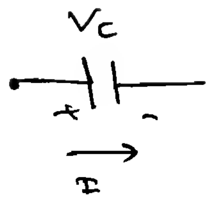
Ex-1 Find the capacitor voltage at $t = 0.5ms$ if switched is closed at $t = 0$. Assume capacitor initially uncharged.



$\therefore \quad \frac{V_i - 0}{1k} = \cancel{V_i - V_c}$

$\therefore \quad \cancel{V_i - V_c - V_o = 0.}$

$\therefore \quad \cancel{10 - V_c - V_o = 0.}$



$\therefore$

$\therefore \quad I = \frac{0-10}{1k}$

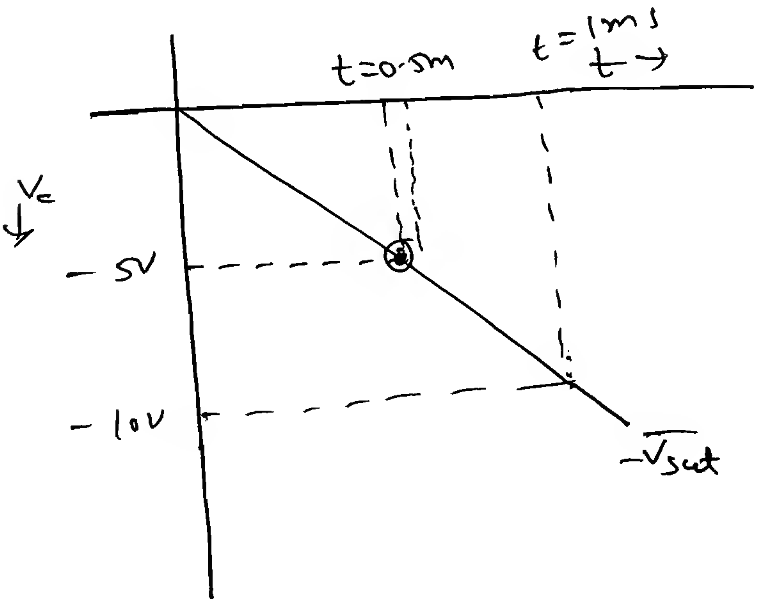
$\therefore \quad \boxed{I = -10mA}$

$\therefore \quad V_c = \frac{1}{C}\int_0^{0.5} I \, dt$

$= \frac{-10\times10^{-3}}{1\times10^{-6}} \times [t]_0^{0.5m}$

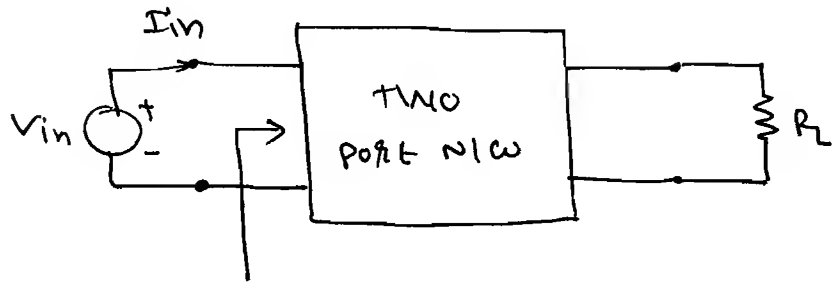
$\therefore \quad V_c = \cancel{-10} \; -5V.$

$\therefore \quad \boxed{V_c = -5V}$



* Input and output Resistance of an amplifier using op-amp.

① Input Resistance:



$$R_{in} = \frac{V_{in}}{I_{in}}.$$

② Output Resistance:

$$R_o = \frac{1V}{I_x}$$

① OC R_L

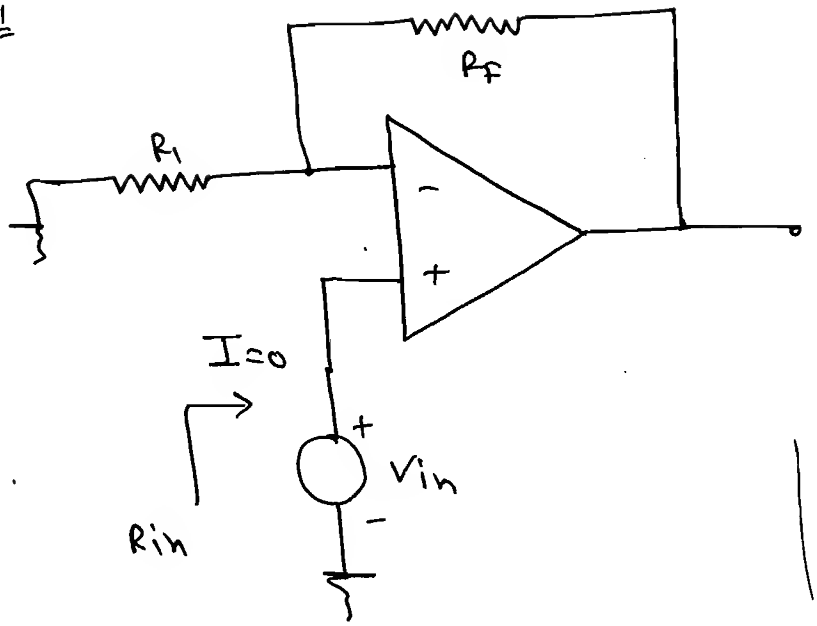
② SC V_{in}

③ Connect 1V Source of O/P terminals

$$\boxed{R_o = \frac{1V}{I_x}}.$$

*

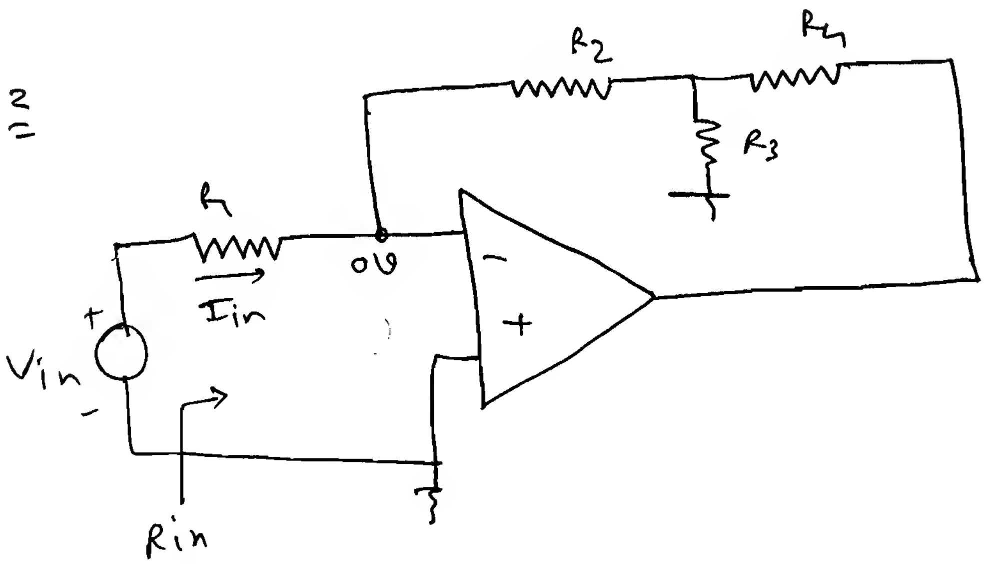
Ex-1



$\therefore \quad R_{in} = \frac{V_{in}}{I_{in}} = \frac{V_{in}}{0}$

$\therefore \quad \boxed{R_{in} = \infty.}$

Ex-2

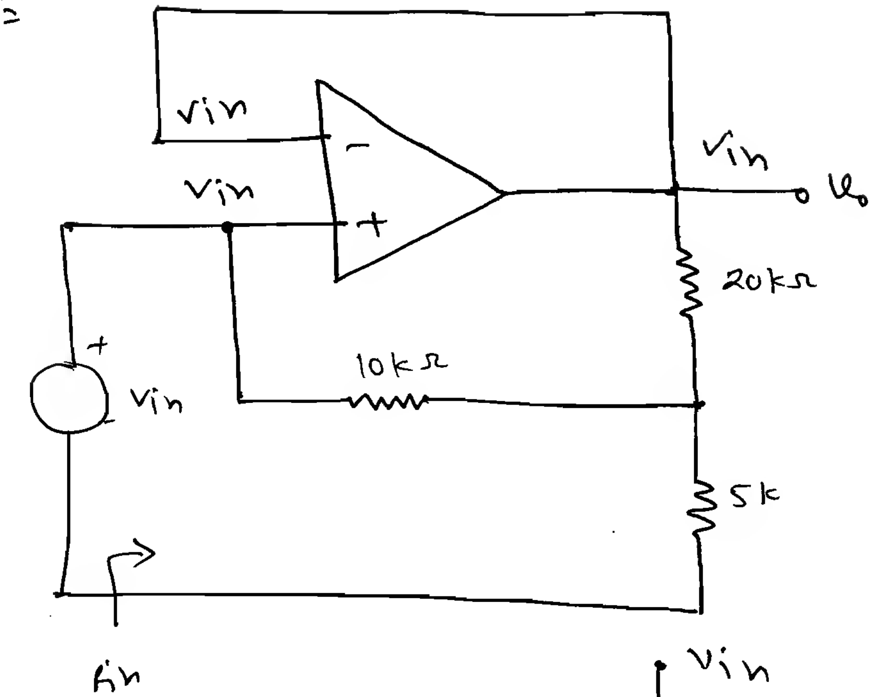


$I_{in} = \frac{V_{in} - 0}{R_1}$.

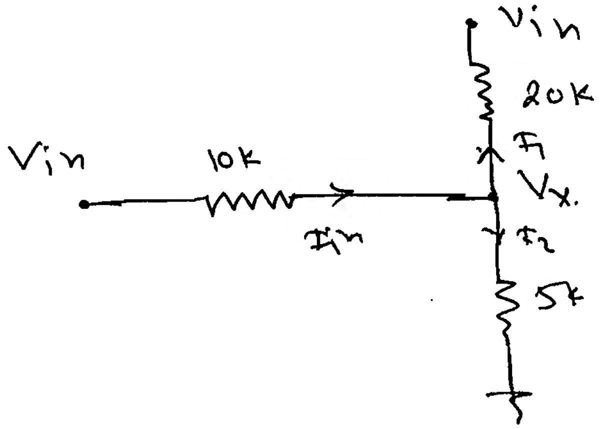
$\therefore \quad R_{in} = \frac{V_{in}}{I_{in}}$

$\therefore \quad \boxed{R_{in} = R_1}$

Ex-3



Ans:



By KCL

$\therefore \quad I_{in} = I_1 + I_2$

$\therefore \quad \frac{V_{in} - V_x}{10} = \frac{V_x - V_{in}}{20} + \frac{V_x}{5}$

$\therefore \quad 2(V_{in} - V_x) = V_x - V_{in} + 4V_x$

$\therefore \quad 7V_x = 3V_{in}$

$\therefore \quad \boxed{V_x = \frac{3V_{in}}{7}}$

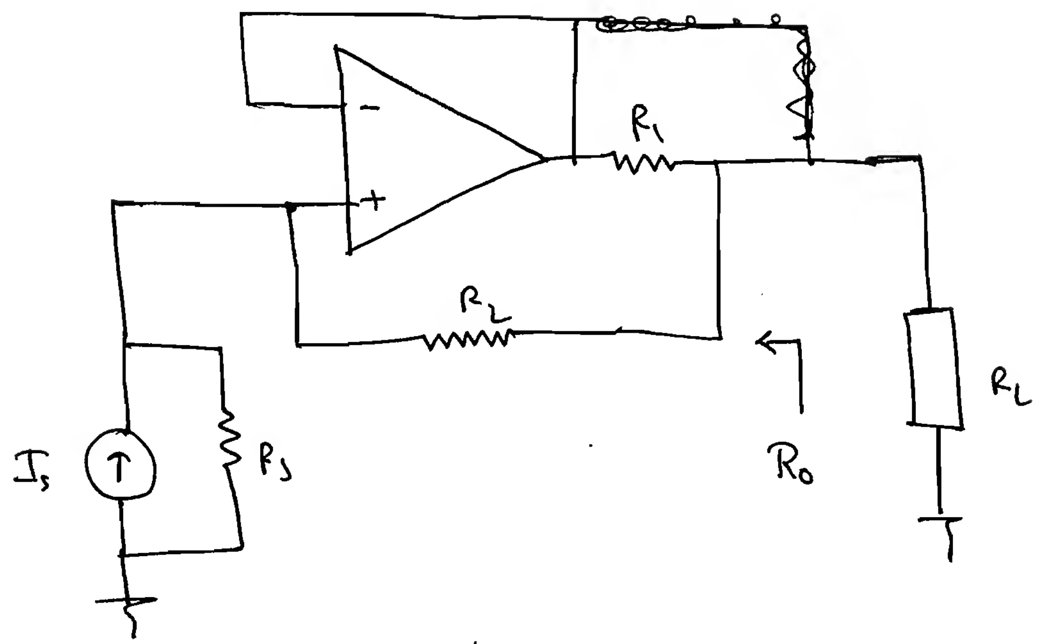
Now, $\quad I_{in} = \frac{V_{in} - V_x}{10}$

$\therefore \quad I_{in} = \frac{V_{in} - \frac{3}{7}V_{in}}{10}$

$\therefore \quad I_{in} = \frac{4}{70} V_{in}$.

$\therefore \quad R_{in} = \frac{V_{in}}{I_{in}} = 70/4 \ k\Omega$.

Ex-1 for o/p R_o



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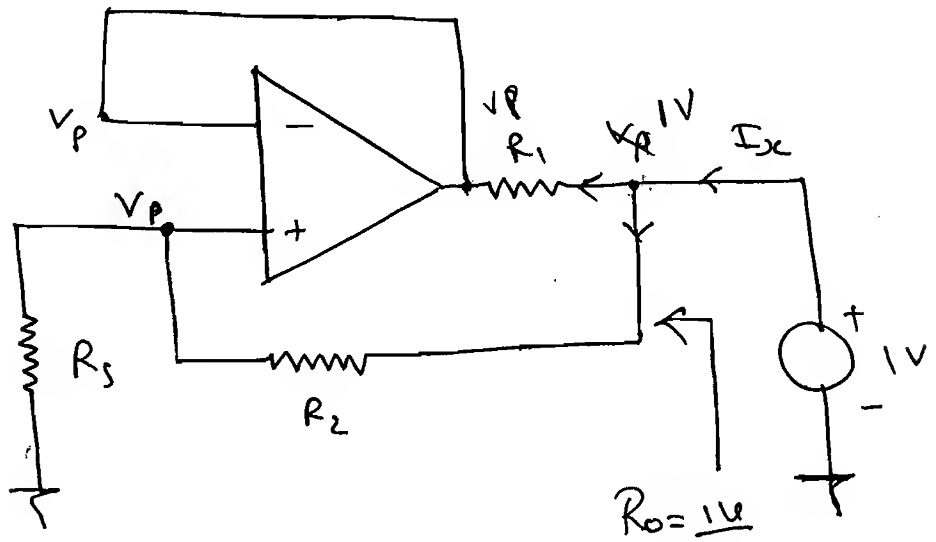


$$R_o = \frac{1V}{I_x}$$

→ $$V_p = \frac{R_S (1)}{R_S + R_2} \Rightarrow 1 - V_p = \frac{R_2}{R_2 + R_1}$$

$$I_x = \frac{1 - V_p}{R_1} + \frac{1 - V_p}{R_2}.$$

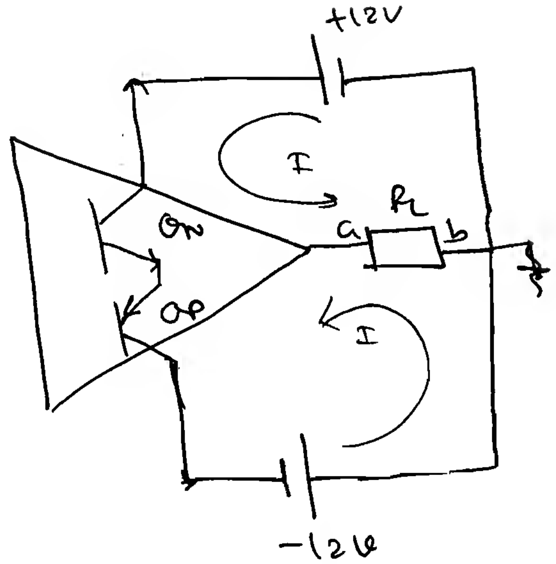
$$\therefore I_x = (1 - V_p)\left[\frac{1}{R_1} + \frac{1}{R_2}\right].$$

$$\therefore I_x = \left[\frac{\cancel{R_2}}{R_2 + R_S}\right]\left[\frac{R_1 + R_2}{R_1 \cdot \cancel{R_2}}\right]$$

$\therefore \quad R_o = 1/I_x$

$$\therefore \quad \boxed{R_o = \frac{R_2 + R_3}{1 + \frac{R_2}{R_1}}}$$

*



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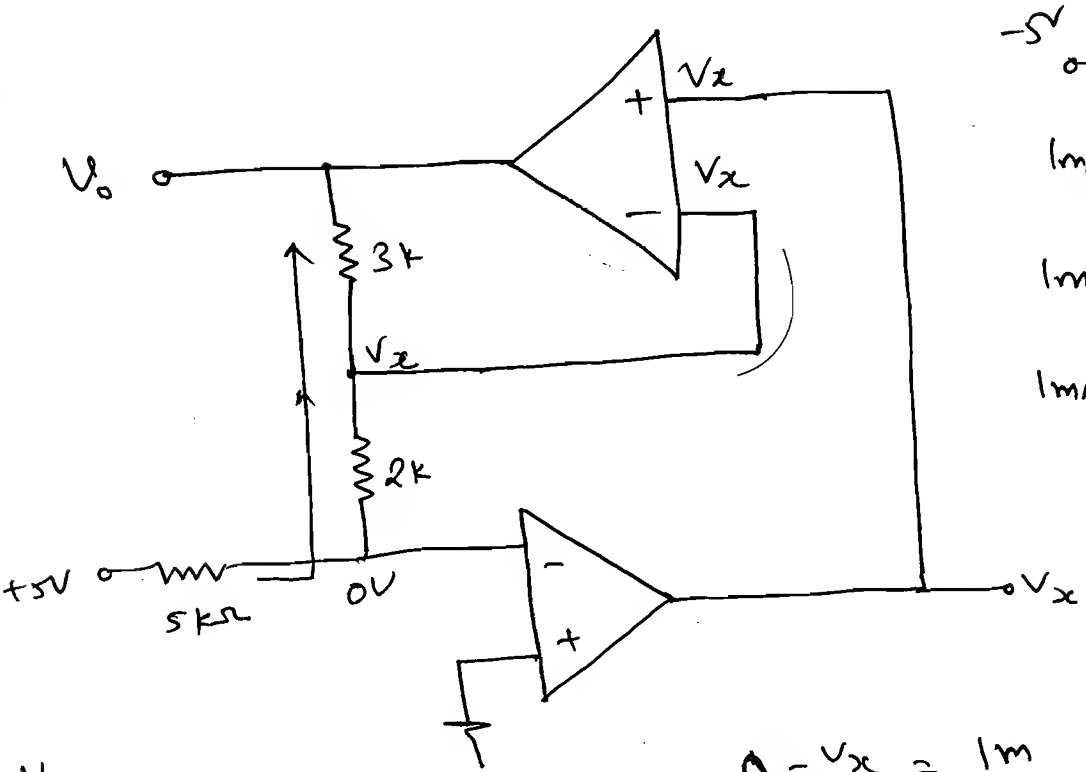
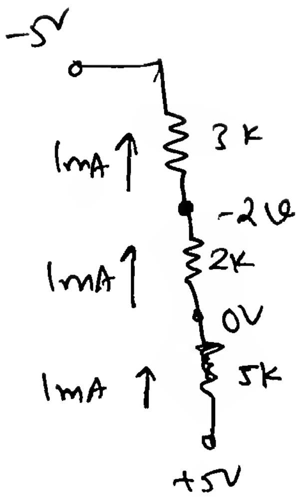
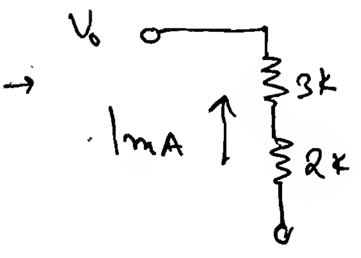




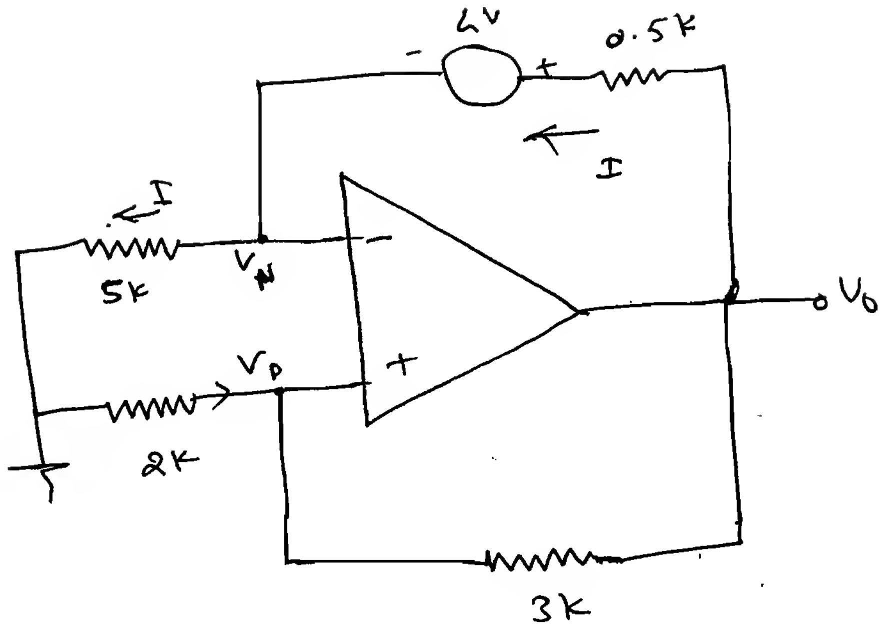


$V_o = -5V \quad 0V$

$$\therefore \quad \frac{0 - V_x}{2K} = 1m$$

$$\therefore \quad \boxed{V_x = -2V}$$

Ex-2



$\rightarrow$ $V_P = \frac{2}{5} V_0$.

$V_N = V_P = \frac{2}{5} V_0$.

$\therefore \quad \frac{0 - V_N}{5} = \frac{V_N + 4 - V_0}{0.5}$

$\therefore \quad -\frac{\cancel{2} V_0}{25} = \cancel{2}\left(\frac{2}{5} V_0 + 4 - V_0\right)$.

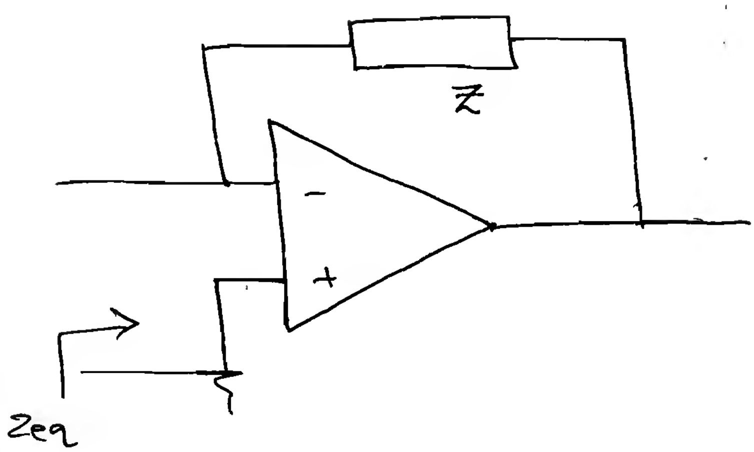
$\therefore \quad -\frac{V_0}{\cancel{25}\,5} = \frac{2V_0 + 20 - \cancel{2}5 V_0}{\cancel{5}}$

$\therefore \quad -V_0 = 10V_0 + 100 - 25V_0$.

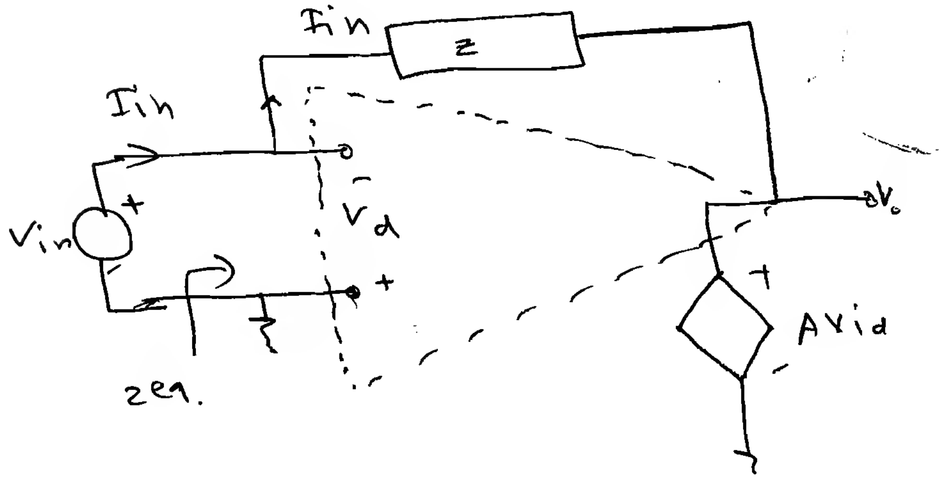
$\therefore \quad 14V_0 = 100$

$\therefore \quad \boxed{V_0 = \frac{50}{7} \text{ V.}}$

* Miller's effect:



$|||$



$\rightarrow \quad V_{in} - zI_{in} - AV_{id} = 0$

$\therefore \quad I_{in} = \dfrac{V_{in} - AV_{id}}{z}$

But, $\quad -V_{id} - V_d = 0$

$\therefore \quad V_d = -V_{in}$

$\therefore \quad I_{in} = \dfrac{V_{in} + AV_{in}}{z}$

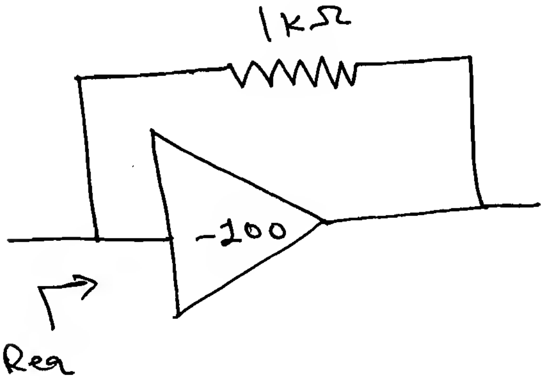
$\therefore \quad \boxed{Z_{eq} = \dfrac{V_{in}}{I_{in}} = \dfrac{z}{1+A}}$

NOTE: Miller's effect is seen only for inverting amplifier.

e.g. \ CE amplifier suffers from miller's effect.

– There is no miller's effect for CB and CC amplifier.

*

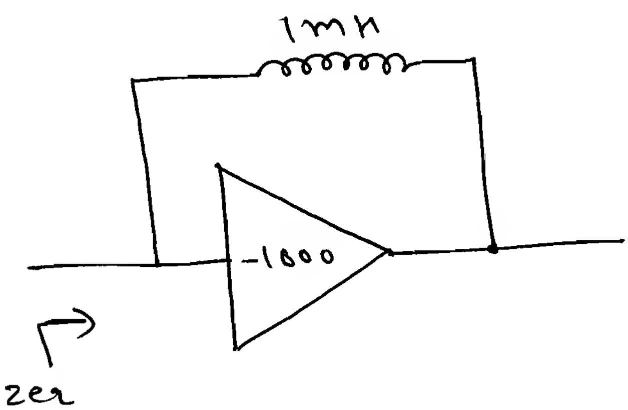


$\therefore Z_{eq} = \cancel{Z}$

$R_{eq} = \frac{R}{1+A} = \frac{1k}{1+100}$

$= \frac{1000}{101} = 10\,\Omega$

*

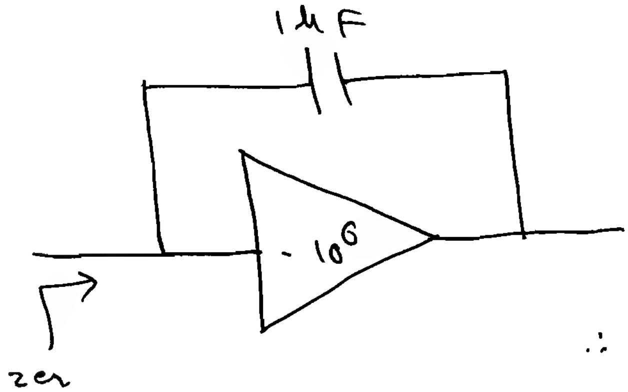


$\therefore Z_{eq} = \frac{Z}{1+A} = \frac{j\omega L}{1+1000} = \frac{sL}{1+1000}$

$\therefore sL_{eq} = \frac{sL}{1+1000} =$

$\therefore \boxed{L_{eq} = \frac{\frac{1}{1000}}{1+1000} = 1\,\mu H}$

*



$Z_{eq} = \frac{Z}{1+A} =$

$\therefore \frac{1}{sC_{eq}} = \frac{\frac{1}{sC}}{1+A}$

$\therefore C_{eq} = C(1+A)$

$\therefore C_{eq} = \frac{10^{-6}}{10^{+6}}$

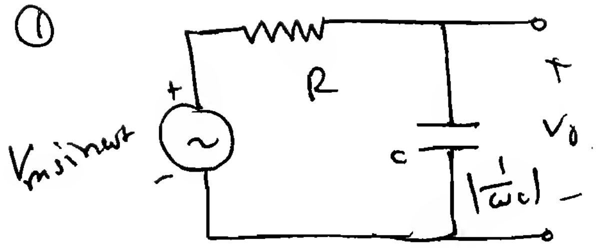
$\boxed{C_{eq} = \cancel{10^{-12}}\,F}$

$\boxed{C_{eq} = 1\,F}$

$\therefore \boxed{C_{eq} = (1+A)C}$

miller's multiplication

①



$\tau = Rc$

$\tau = R_{th} C.$

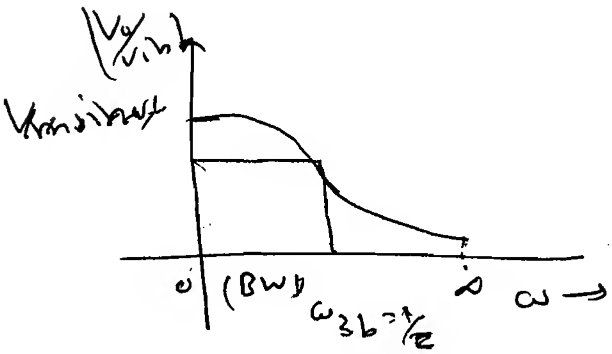
$\therefore \quad \left|\frac{1}{2\pi f c}\right|$

as $f \to$ high $\left|\frac{1}{2\pi f c}\right| = 0$ so S.C.

so, $V_0 = 0$.

$f \to$ Low $\left|\frac{1}{2\pi f c}\right| = \infty$ so O.C.

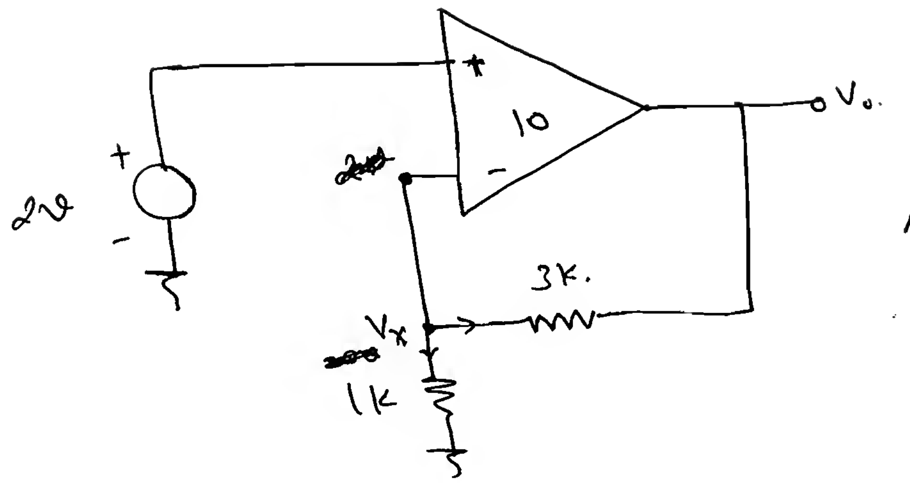
$\therefore$ so, $V_0 = \sin\omega t$.



$$\therefore \quad BW = \frac{1}{\tau} = \frac{1}{RC}.$$

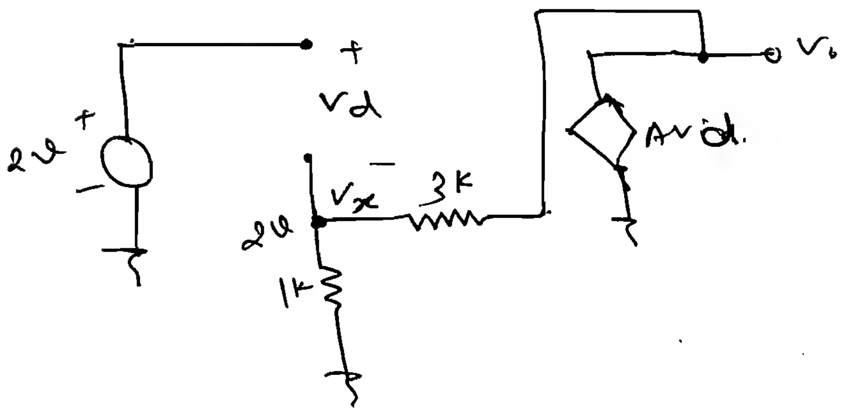
$\therefore \quad C_{eq} \uparrow \Rightarrow \tau \uparrow \Rightarrow BW \downarrow.$

Ex-1



$A_{OL} = 10$ find $V_o = ?$

|||



$$\therefore V_x = V_o\left(\frac{1}{4}\right).$$

$$\therefore V_o = 10V_d.$$

and $V_d = 2 - V_x$

$$\therefore V_d = 2 - \left(\frac{V_o}{4}\right).$$

$$\therefore V_o = 20 - \frac{5V_o}{2}.$$

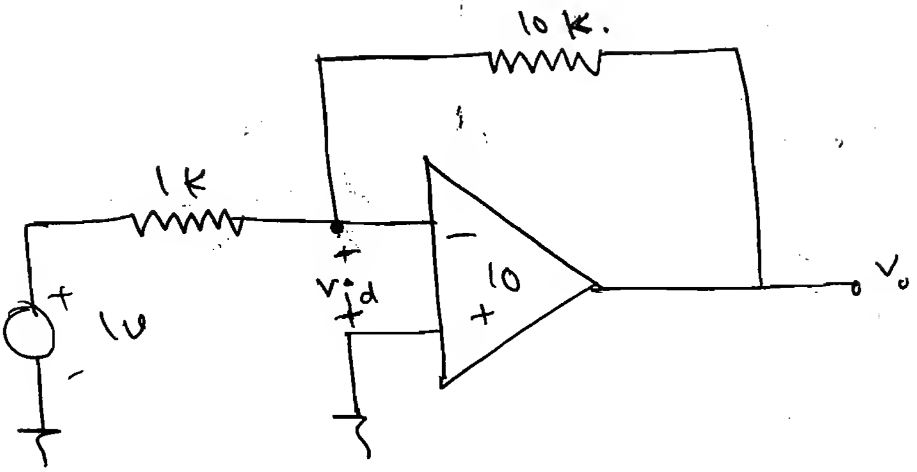
$$\therefore \frac{7V_o}{2} = 20$$

$$\therefore \boxed{V_o = \frac{40}{7}}\ v$$

$$\therefore A_v = \frac{V_o}{2v}.$$

$$\therefore \boxed{A_v = \frac{20}{7}}, \quad A_{OL} = 10.$$

Ex 2 Find V_o. $A_{OL} = 10$.



$$\frac{1 + V_{id}}{1k} = \frac{-V_{id} - V_o}{10k}.$$

$\therefore$ $V_o = A V_{id}$.

$\therefore$ $V_o = 10 V_{id}$

$$\therefore \frac{1 + \frac{V_o}{10}}{1k} = \frac{-\frac{V_o}{10} - V_o}{10}$$

$$\therefore 10 + V_o = \frac{-V_o - 10V_o}{10}$$

$\therefore$ $\cancel{100 + 10V_o = V_o - 10V_o}$

$\cancel{V_o = 100V}$.

$\cancel{100 + V_o = V_o - 10V_o}$

$\boxed{\cancel{V_o = -10}}$

$\therefore$ $100 + 10V_o = -V_o - 10V_o$.

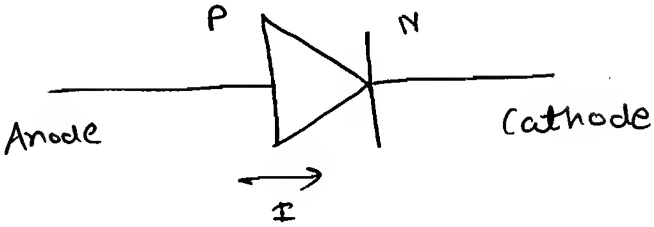
$$\frac{100}{21} = -V_o$$

$\therefore$ $\boxed{V_o = -4.76\ v.}$

4.76
21) 100
84
160

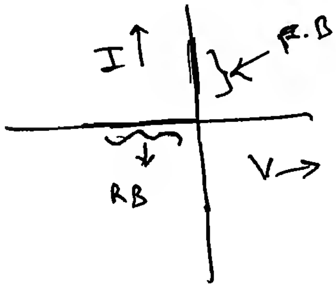
☆ Diode Applications:

→



→ A diode is forward bias when anode is more +ve than cathode.

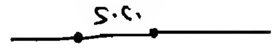
→



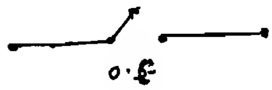
piece-wise Linear model.

Models

FB: $I > 0 \Rightarrow V = 0$



RB: $V < 0 \Rightarrow I = 0$



if $I = +ve \rightarrow$ F.B.

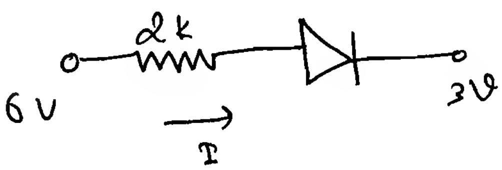
$I = -ve \rightarrow$ R.B.

But I never −ve so

$I = 0 \Rightarrow$ R.B.

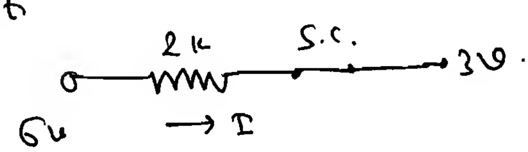
Ex-1 Check whether Diode is F.B. or not. also find the value of current flow:

①



⇓

Let



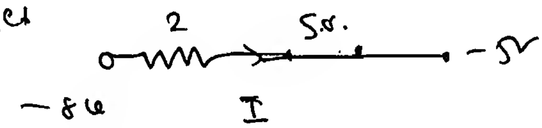
$\therefore I = \frac{6-3}{2}$

$\therefore \boxed{I = 1.5 \text{ mA}} > 0$

So, $\boxed{\text{F.B.}}$

②

Let



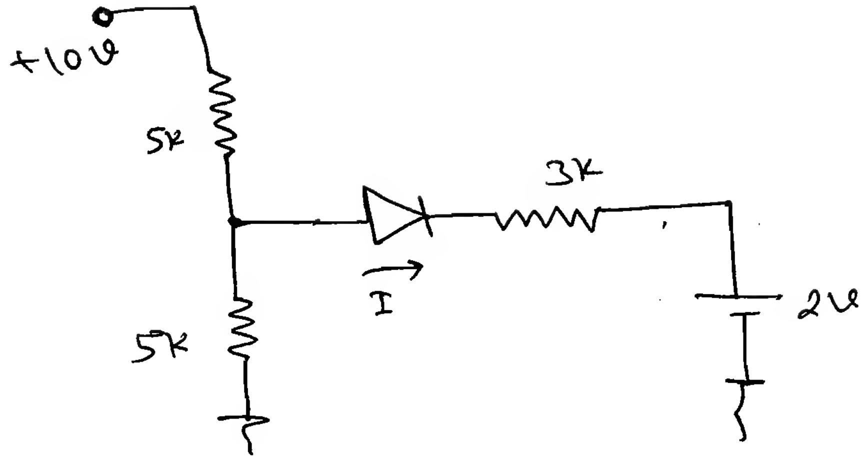
$\therefore I = \frac{+8-5}{2}$

$\therefore I = +1.5 \text{ mA}$

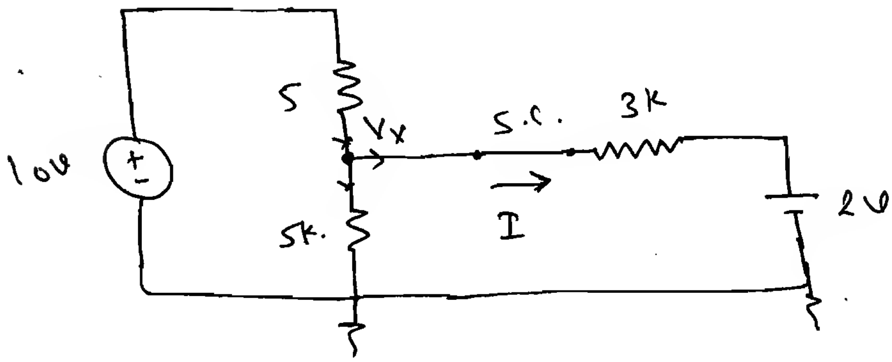
So, F.B.

and $\boxed{I \neq 0}$

Ex-3



⇓



$$\therefore \frac{10 - V_x}{5} = \frac{V_x}{5} + \frac{V_x - 2}{3}$$

$$\therefore 2 - \frac{V_x}{5} = \frac{V_x}{5} + \frac{V_x}{3} - 2/3$$

$$2 + 2/3 = \frac{2V_x}{5} + \frac{V_x}{3}$$

$$\therefore \frac{8}{3} = \frac{6V_x + 5V_x}{15}$$

$$\boxed{V\ \frac{40}{11} = V_x}$$

$$\therefore I = \frac{V_x - 2}{3k}$$

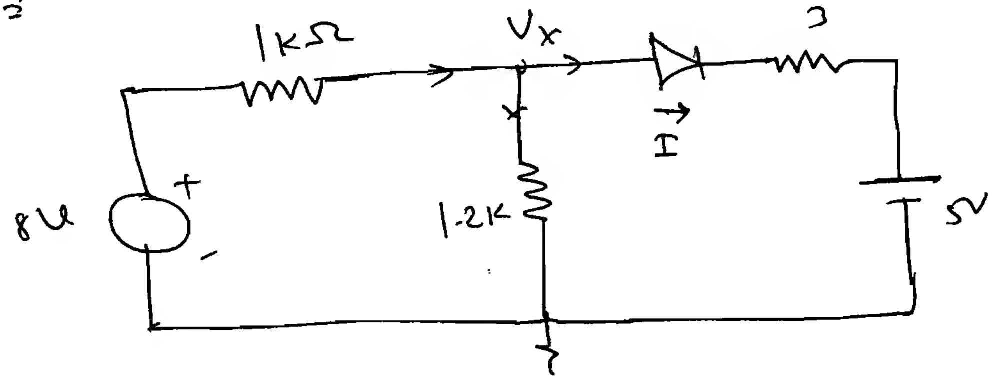
$$\therefore I = \frac{\frac{40}{11} - 2}{3k}$$

$$I = \frac{18}{3}$$

$$\therefore \boxed{I = \frac{6mA}{11}}$$

S, FB.

Ex-4



$$\rightarrow \quad \frac{8 - V_x}{1} = \frac{V_x}{1.2} + \frac{V_x - 5}{3}.$$

$$\therefore \quad 8 - V_x = \frac{5V_x}{6} + \frac{V_x}{3} - 5/3.$$

$$\therefore \quad 8 + \frac{5}{3} = \frac{7V_x}{6} + V_x.$$

$$\therefore \quad \frac{29}{\cancel{3}} = \frac{13V_x}{\cancel{6}\,2}$$

$$\therefore \quad \boxed{\frac{58}{13} = V_x.}$$

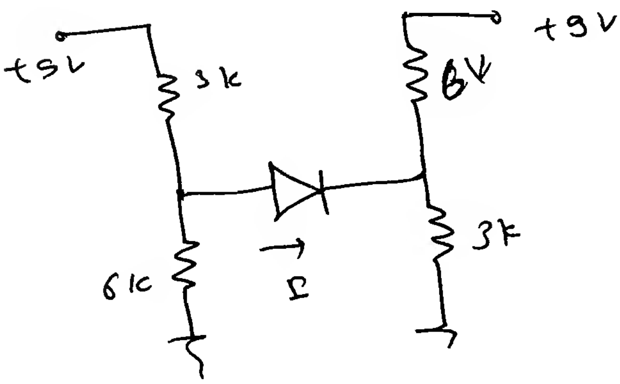
$$\therefore \quad I = \frac{V_x - 5}{3k}$$

$$\therefore \quad I = \frac{\frac{58}{13} - 5}{3k}.$$

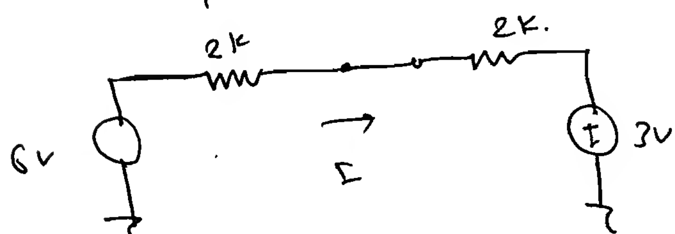
$$\therefore \quad \boxed{I = \frac{-7}{39}\ mA.}$$

So, R.B. $\boxed{I = 0}$

Ex-5



$\Rightarrow$

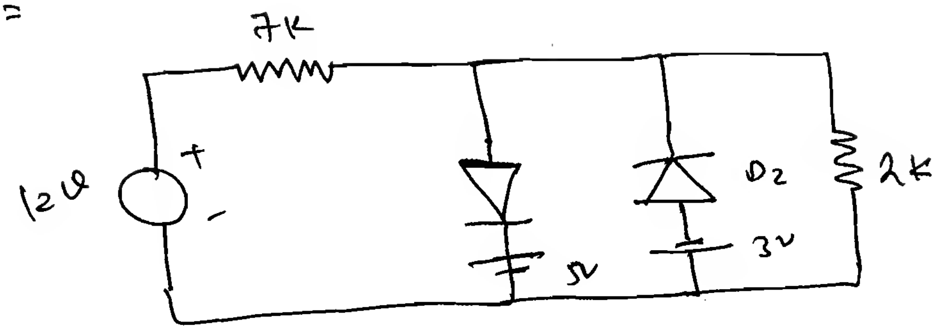


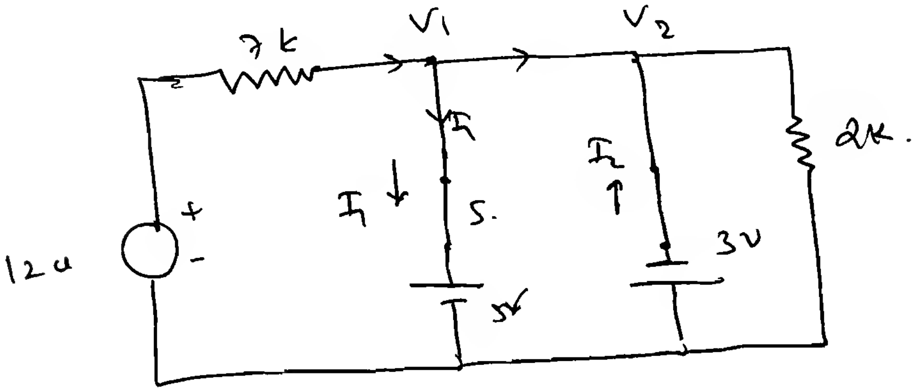
$$I = \frac{6-3}{4}$$

$$I = 3/4$$

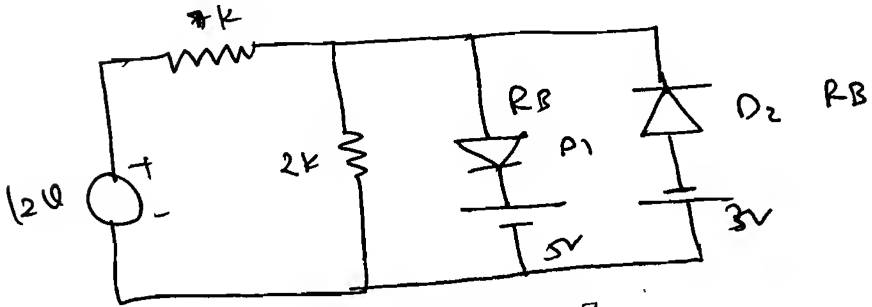
$$I = 0.75\ mA.$$

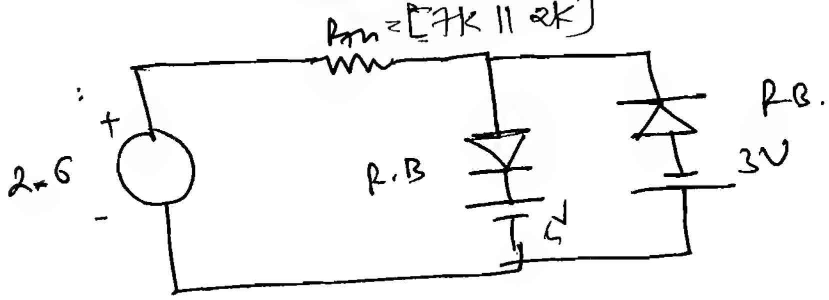
Ex-2





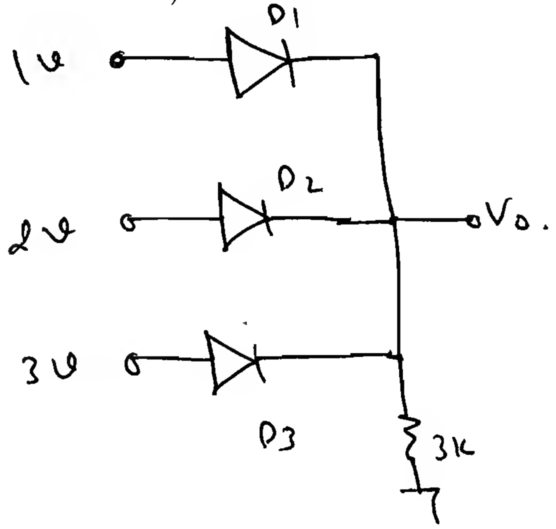
→ $\frac{V_2 = V_1}{A}$ I_1 $\cancel{V_1 = 5}$





Both are R.B.

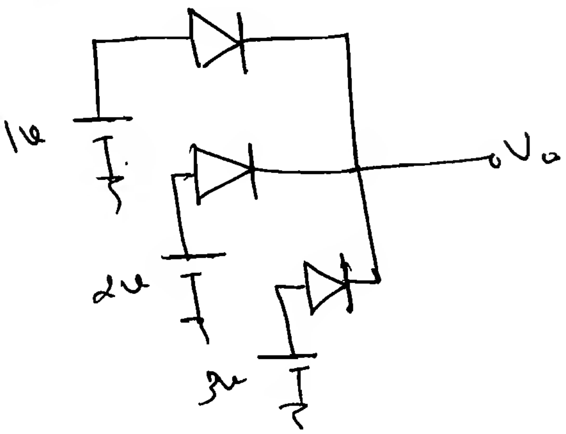
Ex-1 Find Vo, Diode is ideal



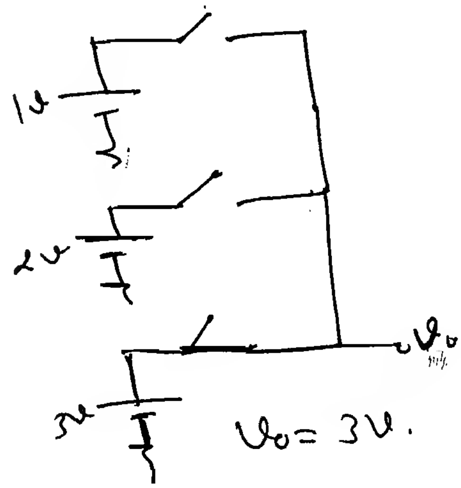
$I_d = I_s e^{V_D/V_t}$ exp operation

$V_D = V_t \ln\left[\frac{I_D}{I_s}\right]$ log operation

→ ① ~~Vr =~~

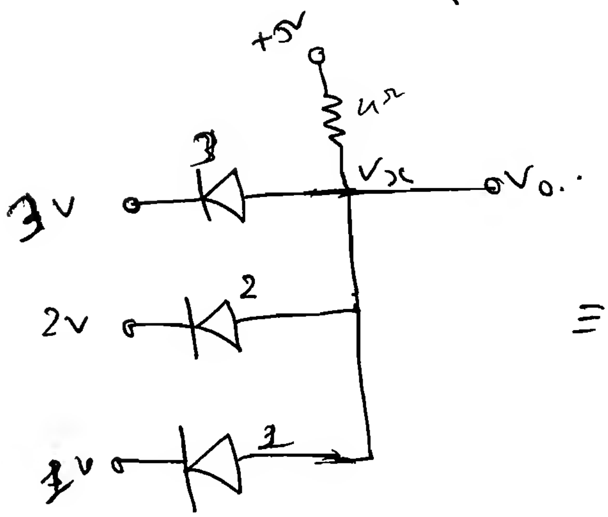


≡

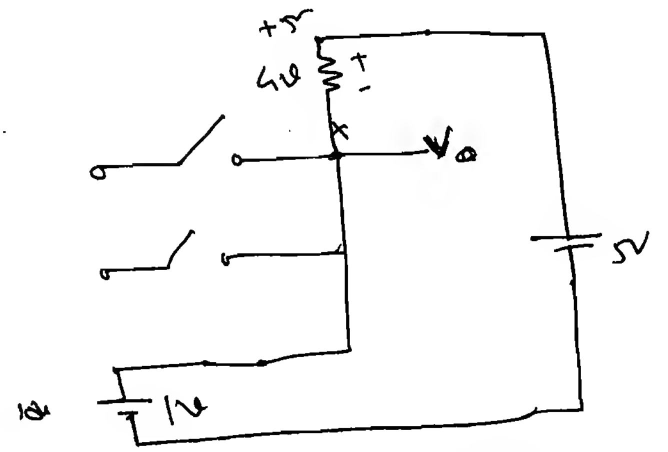


$V_o = 3V$.

Ex-2



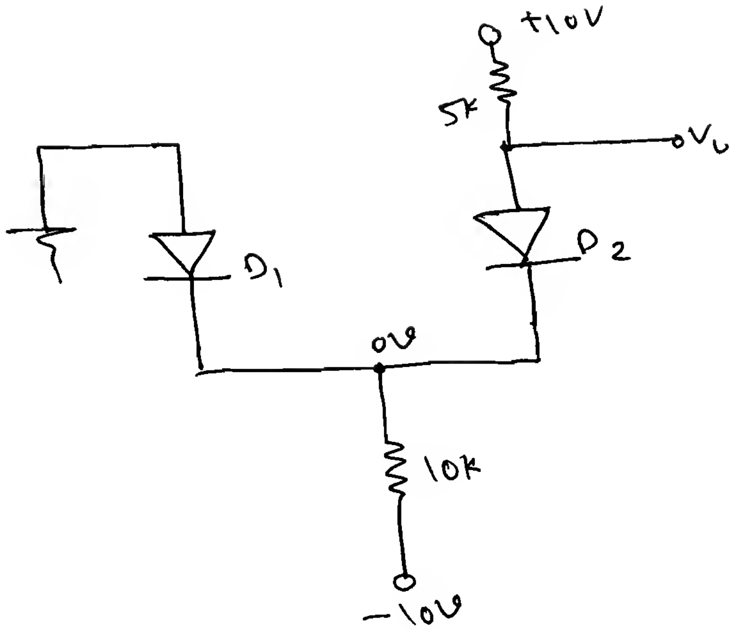
≡



→ 1V Diode experience more potential difference so, it is on ~~adn~~ and D_2 D_3 is off.

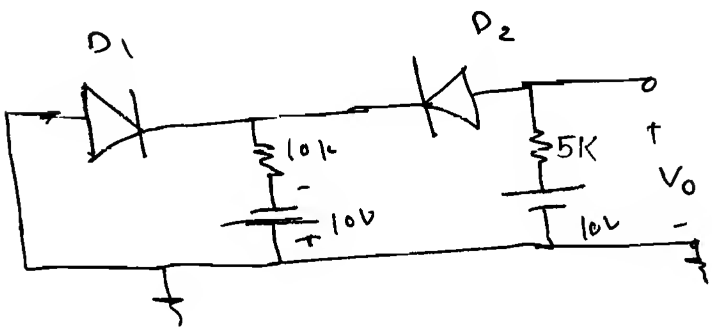
and $V_o = 1V$.

Ex-2

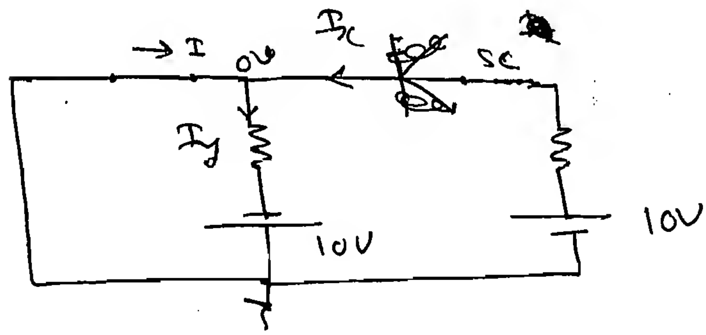


|||

⇒



Ans: Let <u>Test- D_1</u>

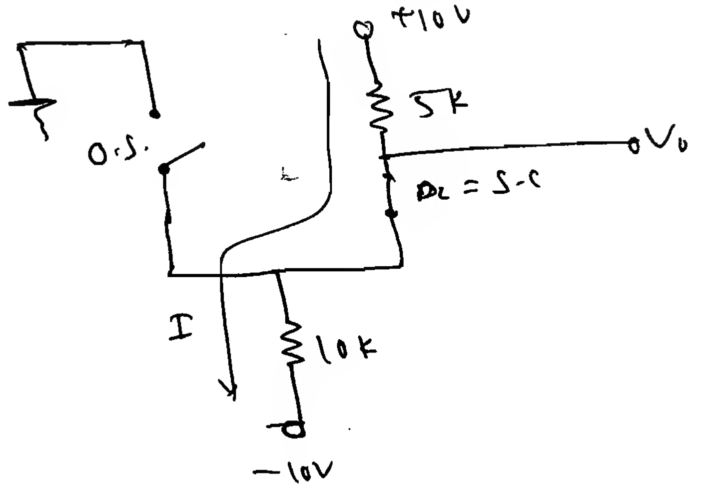


$\therefore \quad I = I_y - I_x.$

$$I = \frac{0-(-10)}{10k} - \left[\frac{10-0}{5k}\right].$$

$\therefore \quad I = -1mA$ (Neg).

$\therefore$ Diode D_1 is in RB.



$$\therefore \quad \frac{V_0 - (-10)}{10} = I.$$

$$\therefore \quad V_0 + 10 = 10I$$

$$\therefore \quad V_0 = \frac{40}{3} - 10$$

$$\therefore \quad \boxed{V_0 = \frac{10}{3}\ V.}$$

$$\therefore \quad I = \frac{10-(-10)}{15}$$

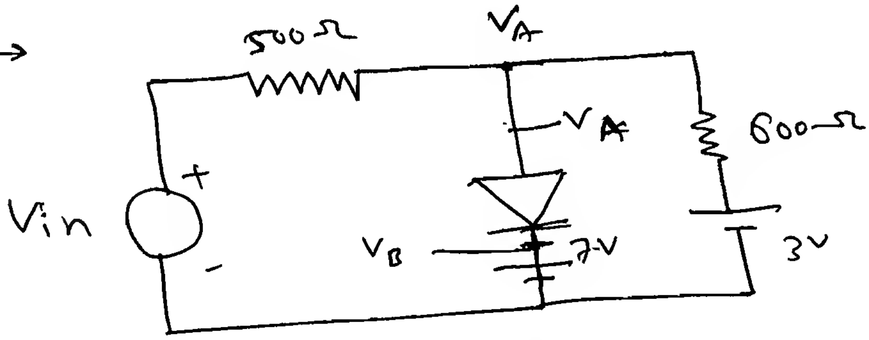
$$I = \frac{20}{15}.$$

$$\therefore \quad I = \frac{4}{3} = 1.33\ mA.$$

$\therefore$ So, D_2 is F-B.

Ex: Find the minimum voltage Vin ~~to~~ for Diode to be FB.

→

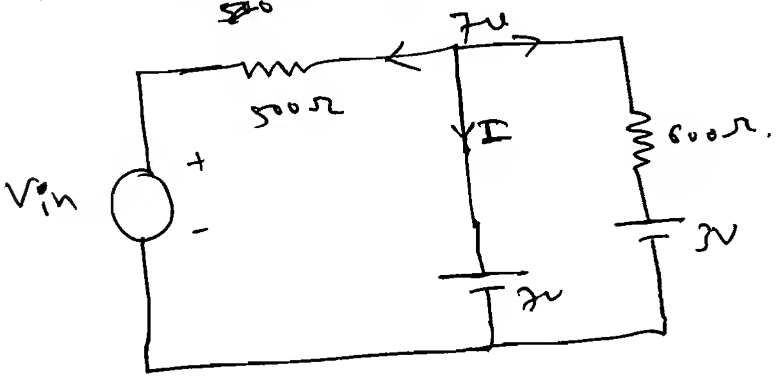


for F-B.

$$\therefore \quad \boxed{V_A - V_B > 0}$$

V_A -

$\therefore$ ~~$\frac{V_{in} - V_A}{500}$~~



$\therefore$ Vin = 10.33 for $I = 0^+$

$\therefore$ so Diode D_1 is in FB when $I > 0$.

$$\rightarrow \boxed{V_{in} > 10.33\ V.}$$

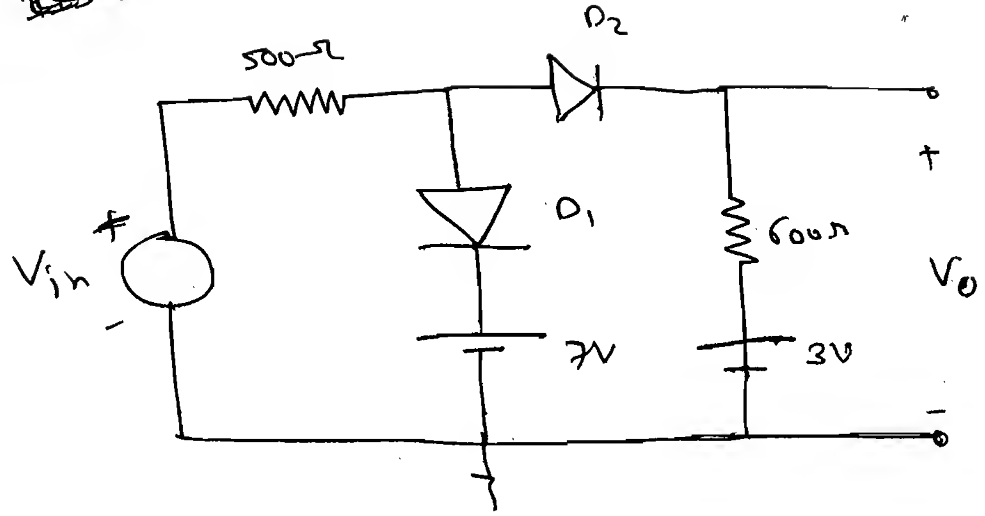
$$\frac{7 - V_{in}}{500} + I + \frac{7-3}{600} = 0$$

Sub $I = 0^+$

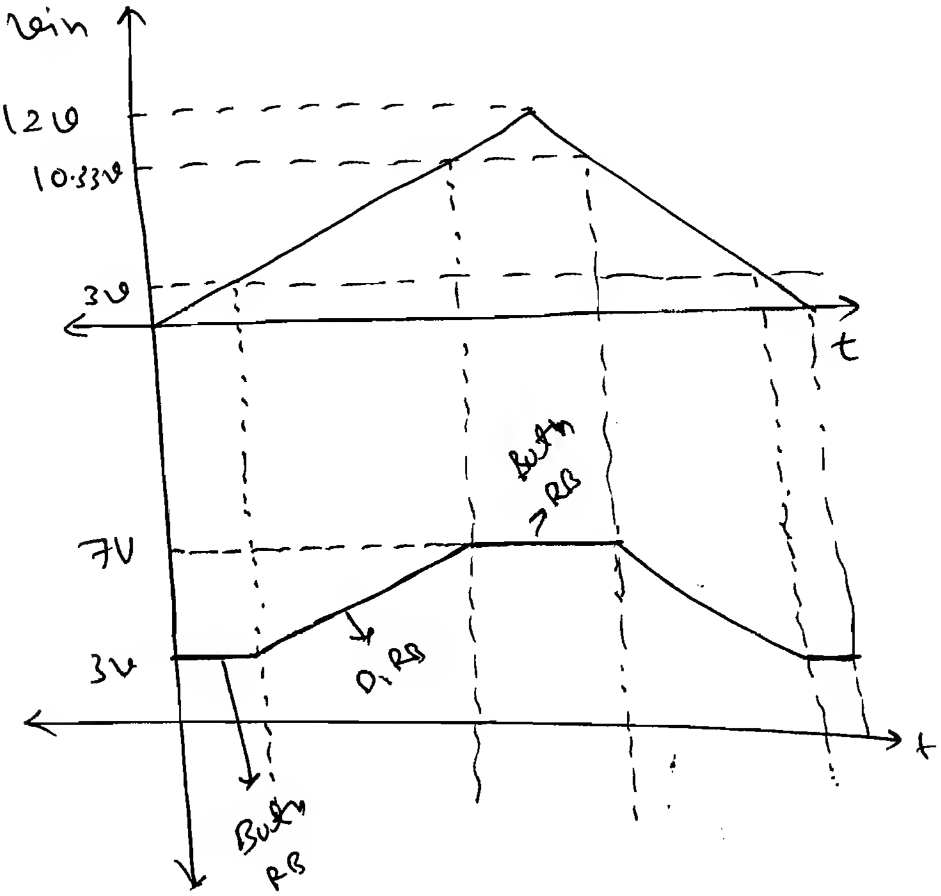
$$\therefore \quad \frac{7 - V_{in}}{500} + \frac{7-3}{600} = 0$$

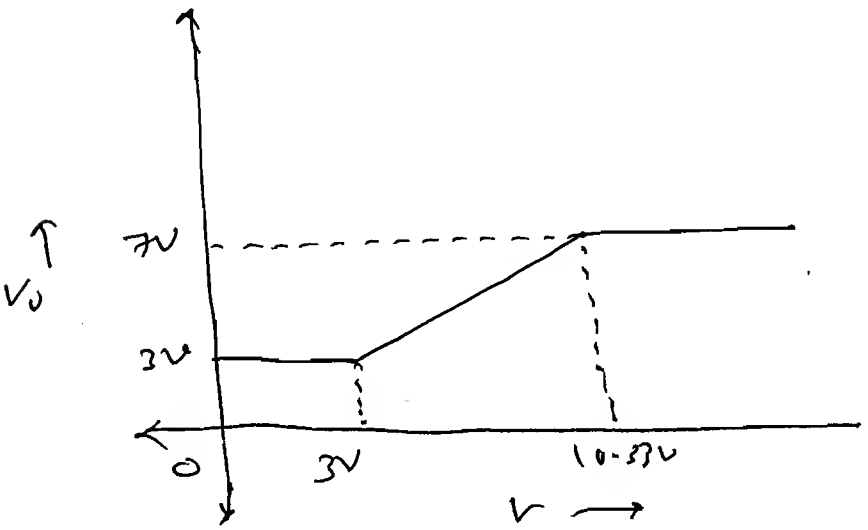
~~ESE~~ &ISC

Ex-1



Ans:

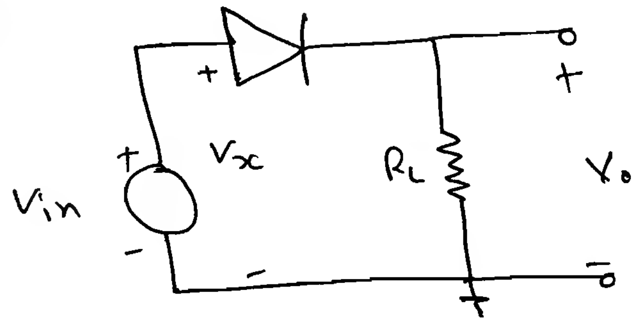




★ Clipperes or Ciping circuits: [limiters]

→ Clipper is a circuits which cuts the portion of the required waveform.

*

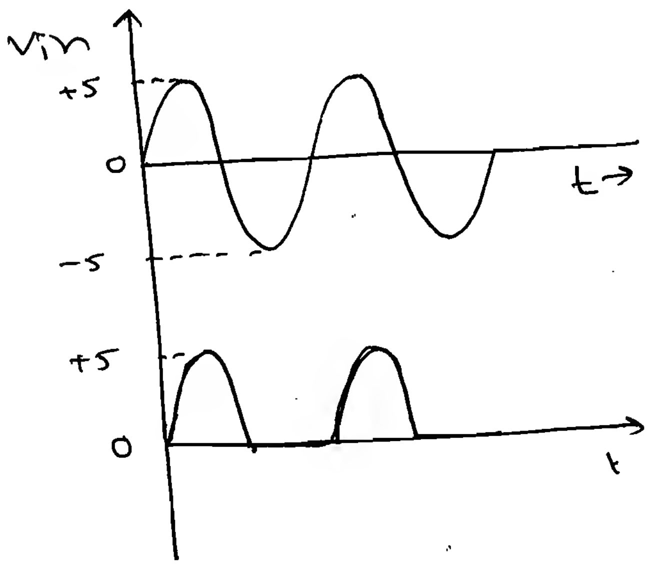


$\therefore V_x = V_{in}$

$\therefore V_{in}$ range: -5 to $+5$

V_x range: -5 to $+5$

V_o range: 0 to $+5$.



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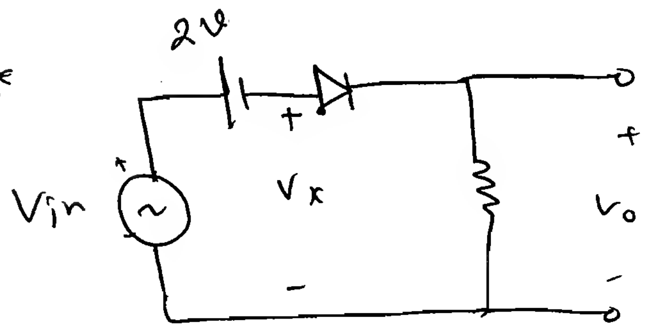
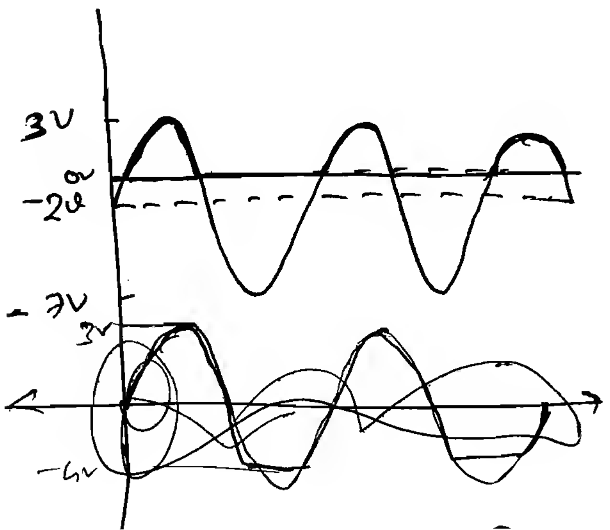


$\therefore V_x = V_{in} - 2V$.

$\therefore V_{in}$ range: -5 to $+5V$.

V_x range: -7 to $3V$.

V_o range: 0 to $3V$.



$\therefore V_o = V_{in} - 2V$.

$V_{in} > V_A - V_B$.

$V_{in} > -2 - 0$

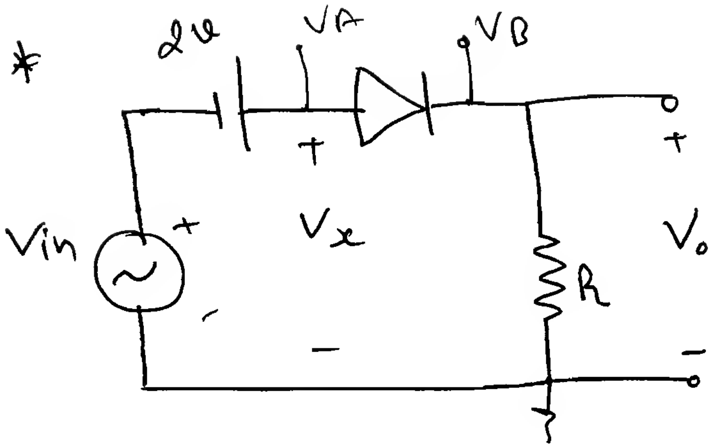
$V_{in} > -2 \rightarrow$ F.B.

$-2 < V_{in} < 5 \rightarrow$ F.B.

$V_o = V_{in} - 2$

$-4 < V_o < +3$.

*



$V_x = V_{in} + 2.$

V_{in} range: -5 to $+5$ V

V_x range: -3 to $+7$ V.

V_o range: 0 to 7V.

$V_{in} > V_A - V_B$

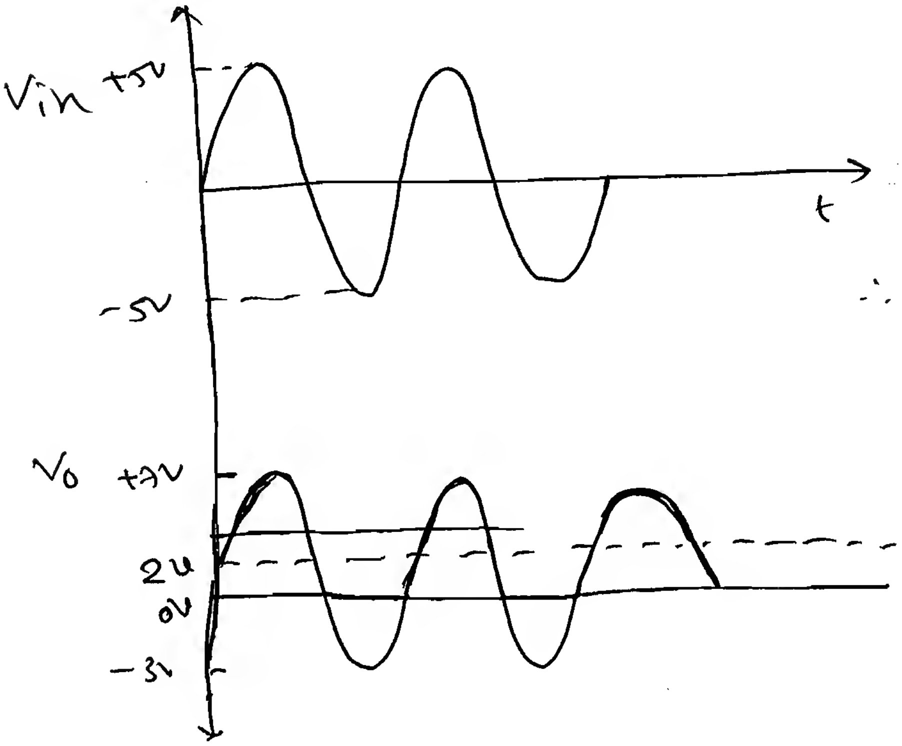
$V_{in} > 2 - 0$

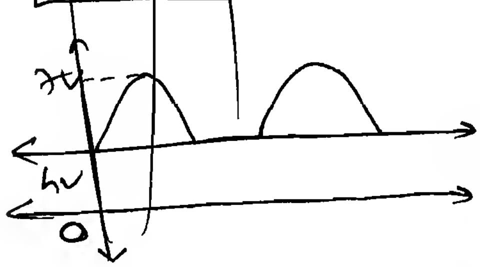
$V_{in} > 2 \rightarrow$ F.B.

$2 < V_{in} < 5 \rightarrow$ F.B.

$V_o = V_{in} + 2$V.

$\therefore \boxed{0 < V_o < 7V}$





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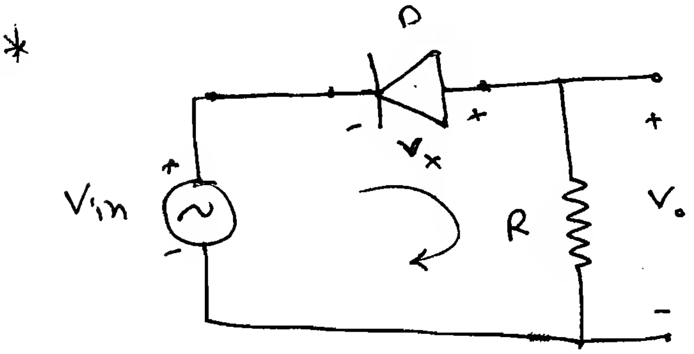


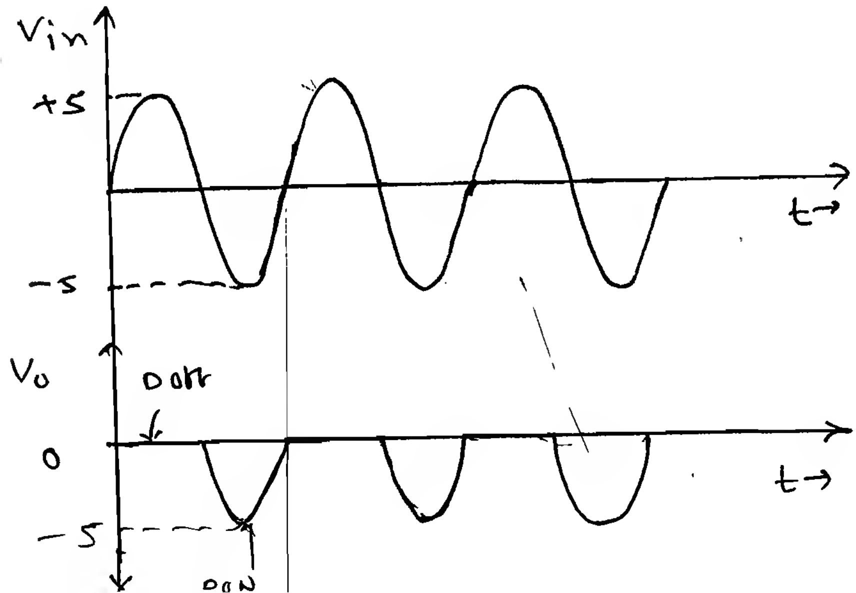
$V_{in} + V_x = 0.$

$\therefore V_x = -V_{in}.$

V_{in} range: -5 to $+5$

V_x range: 5 to -5.

V_o range: 0 to -5.



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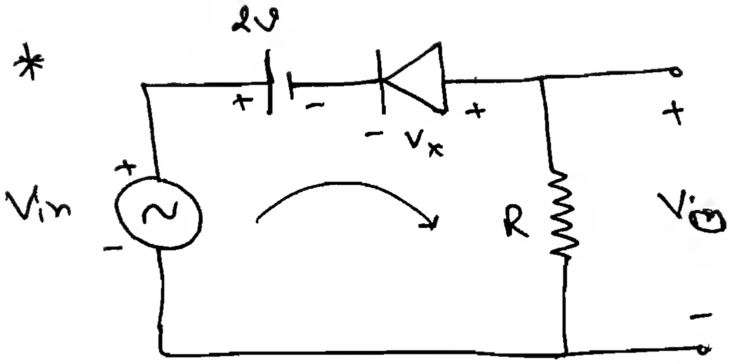


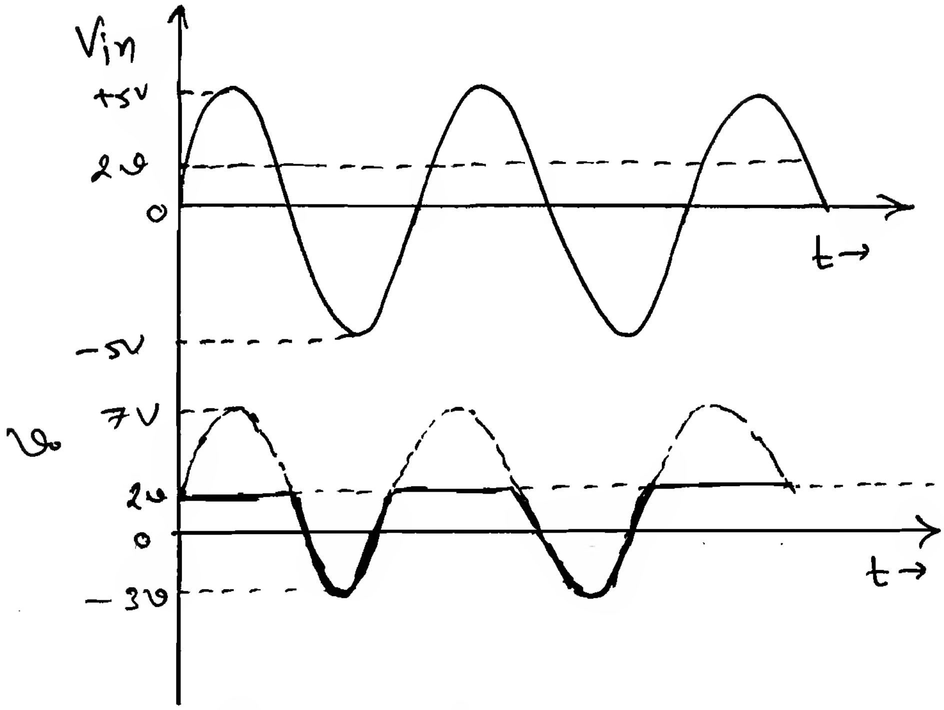
$V_{in} - 2 + V_x = 0$

$\therefore V_x = 2 - V_{in}$.

$\therefore V_{in}$ range: -5 to $+5$ V

V_x Range: 7 to -3.

V_o Range: ~~0 to −3.~~ -7 to 0



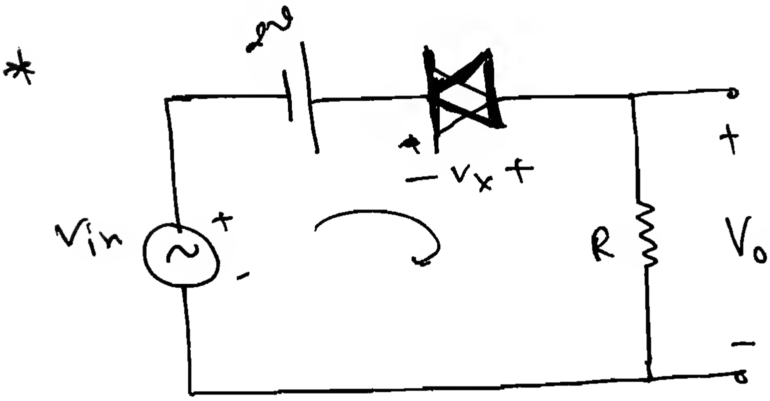
$V_x > 0$

$2 - V_{in} > 0$

$V_{in} < 2$V.

for F.B.

*



$V_{in} + 2V + V_x = 0$

$\therefore V_x = -V_{in} - 2V$

V_x range: 3 to -7 V.

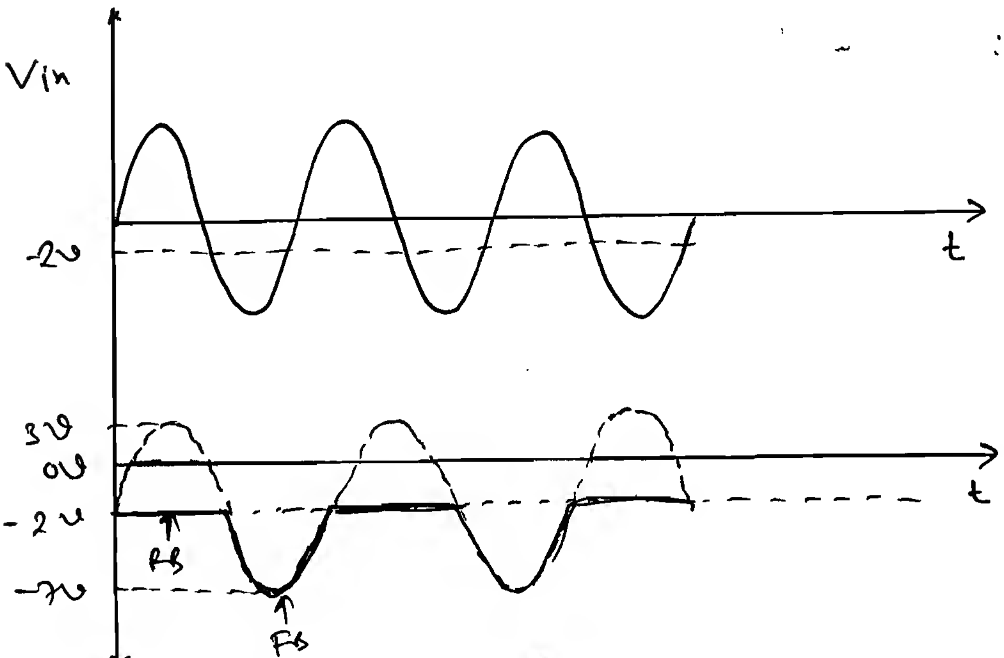
V_o range: 0 to -7 V.

$V_x > 0$

$\therefore -V_{in} - 2V > 0$

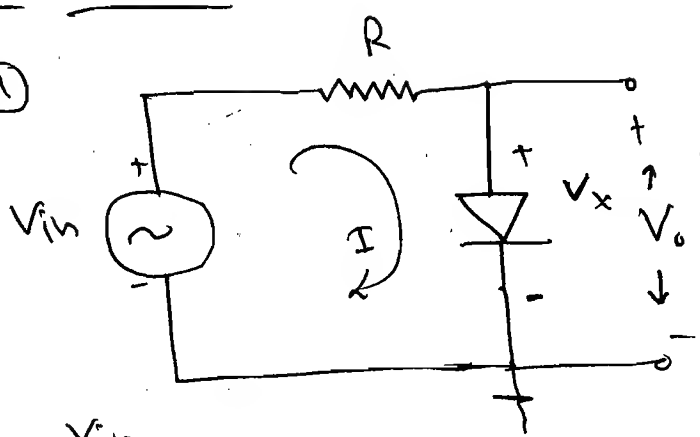
$V_{in} < -2V$.

$V_o = 0$ to -3 V.



* Sketch V_o.

①



$V_{in} - V_x = 0$

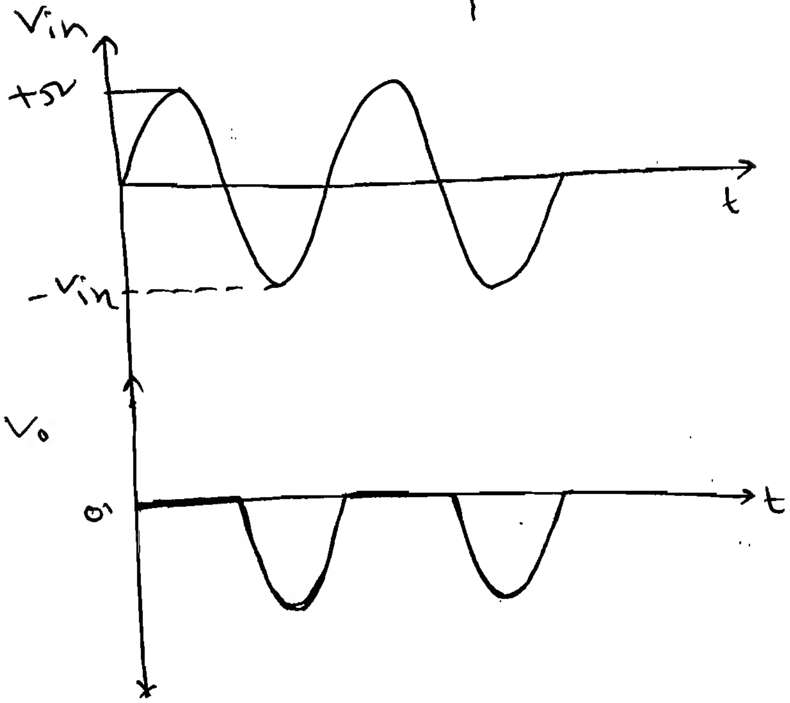
$\therefore V_x = V_{in}$.

$\therefore V_{in}$ range: -5 to $+5$

V_x range: -5 to $+5$.

V_o range: -5 to 0.

F..



F.B $I > 0$

$\therefore I = \frac{V_{in} - 0}{R}$

$I = \frac{V_{in}}{R}, > 0$

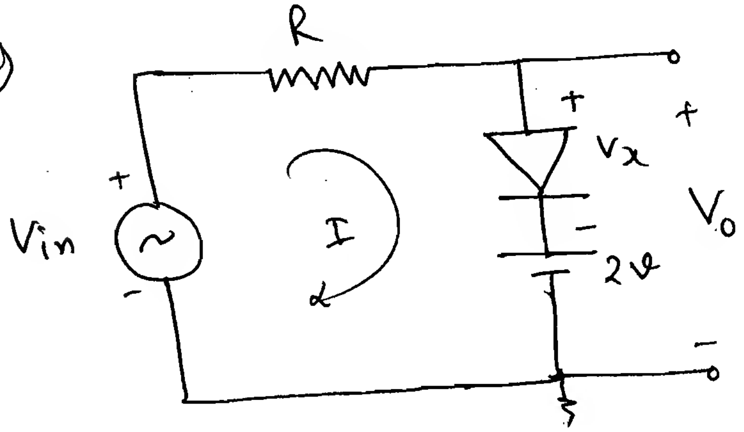
$\therefore \boxed{V_{in} > 0}$ F.B

$V_{in} \le 0$ R.B.

$\therefore V_o = V_{in}, \; V_{in} \not> 0$

$V_o = 0, \; V_{in} > 0$

②



$\therefore$ ~~Vin~~

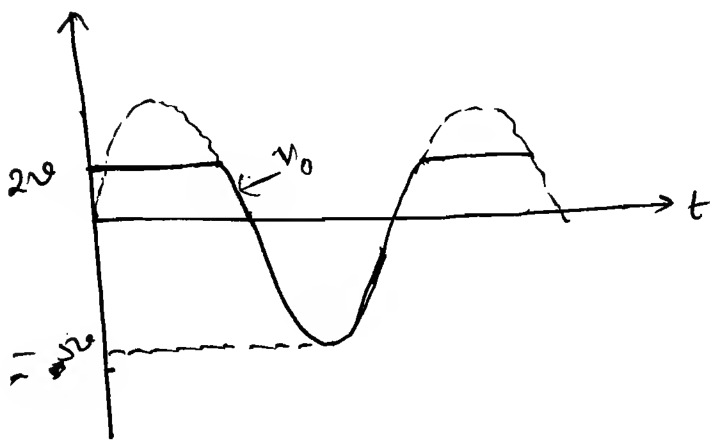
$I = \frac{V_{in} - 2}{R}, > 0$

$\therefore \boxed{V_{in} > 2V} \rightarrow$ F.B $\rightarrow V_o = 2$

R.B. $\boxed{V_{in} \le 2V} \rightarrow V_o = V_{in}$.

$V_o = V_{in} - 2$

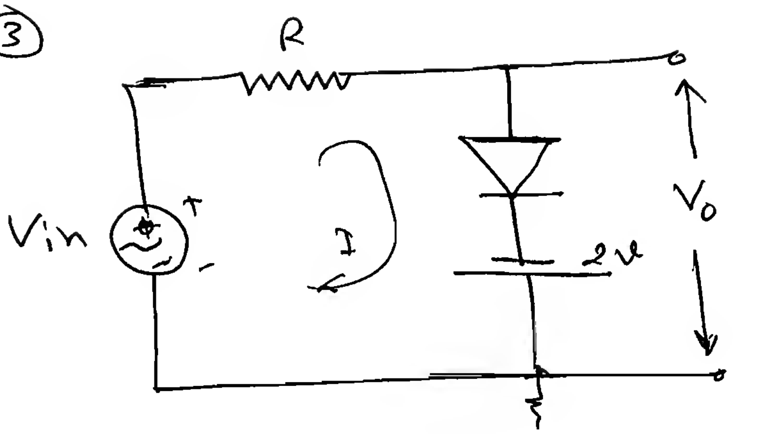
$V_o = -5 - 2$



$\boxed{\begin{array}{c} V_{in} > 2V \\ \Downarrow \\ \text{F.B.} \\ V_o = 2V. \end{array}}$ → F.B. (S.C)

$\boxed{\begin{array}{c} V_{in} < 2V. \\ \Downarrow \\ \text{R.B} \\ V_o = V_{in} \end{array}}$ → R.B (O.C).

③



$$I = \frac{V_{in}+2}{R}$$

for F.B. $I > 0$

$$\therefore \frac{V_{in}+2}{R} > 0$$

$$\boxed{V_{in} > -2} \rightarrow \text{F.B.}$$

$\Downarrow$

S.C.

$\Downarrow$

$V_o = -2v$

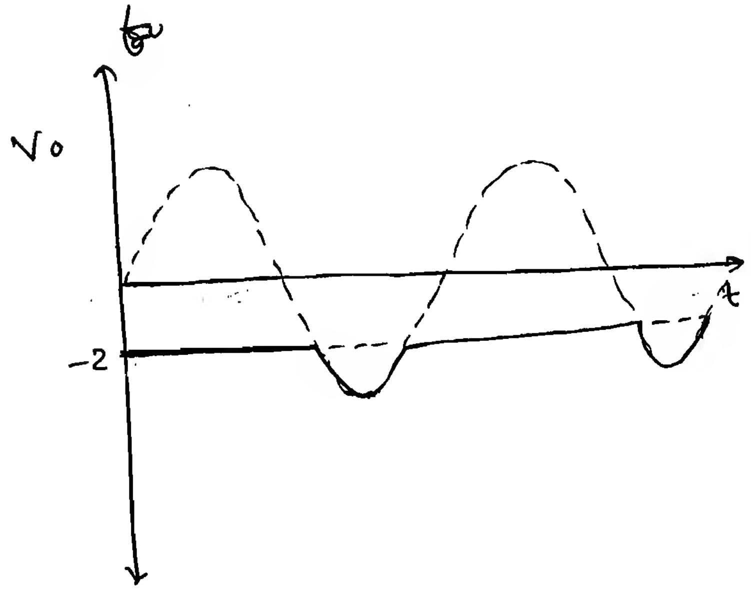
for R.B $I \leq 0$.

$$\therefore \boxed{V_{in} \leq -2}$$

$\Downarrow$

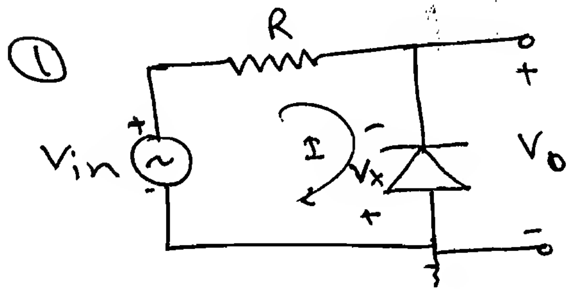
O.C.

$V_o = V_{in}$.



* Sketch v_o:

①



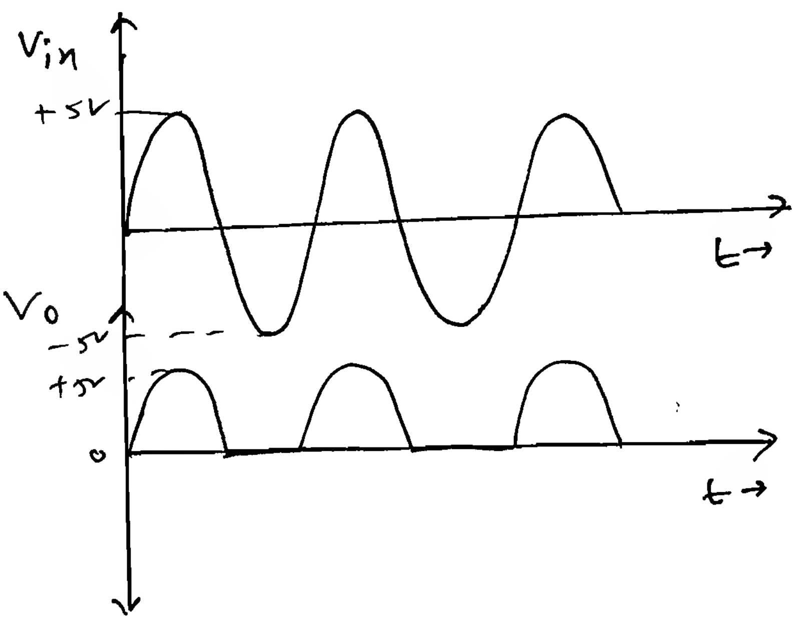
$V_{in} + V_x = 0$

$\therefore V_x = -V_{in}$

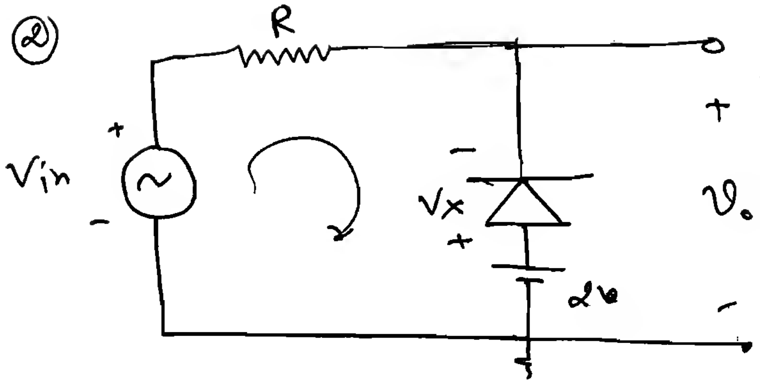
V_{in} range: -5 to $+5$

V_x range: $+5$ to -5.

V_o range: ~~0 to +5~~, 5 to 0.



(2)



$V_{in} + V_x - 2V = 0$

$\therefore V_x = 2 - V_{in}.$

$\therefore V_{in}$ range: -5 to 5 V

V_x range: 7 to -3V

V_o range: 7 to 0 V.

$V_x > 0 \rightarrow$ F.B.

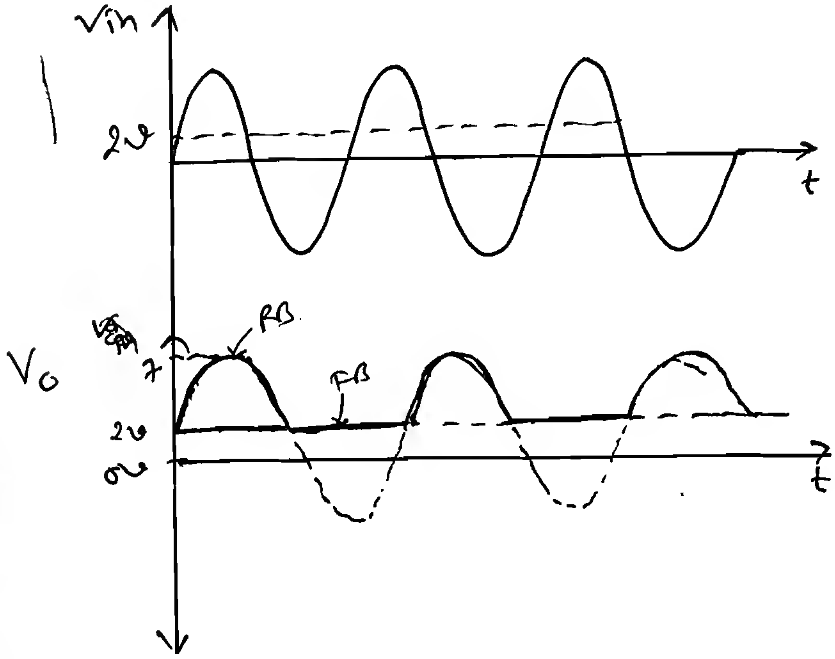
$2 - V_{in} > 0$

$\boxed{V_{in} < 2V}$

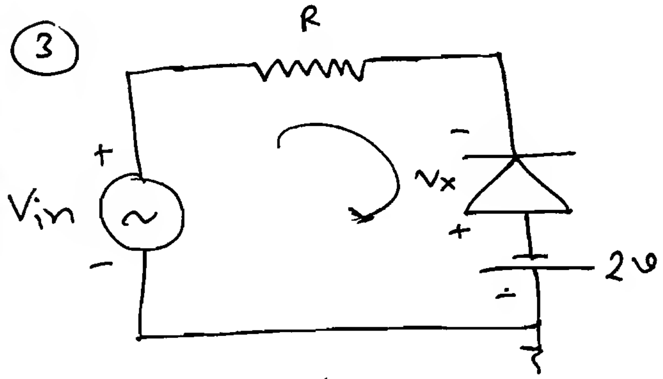
$V_o = 2V.$

$V_{in} \ngeq 2V \rightarrow$ RB

$V_o = V_{in}.$



(3)



$V_{in} + V_x + 2V = 0$

$\therefore V_x = -2 - V_{in}.$

V_{in} range: -5 to $+5$.

V_x range: $+3$ to $-7V$

V_o range: $+3$ to $0V$.

$V_x > 0 \rightarrow$ F.B.

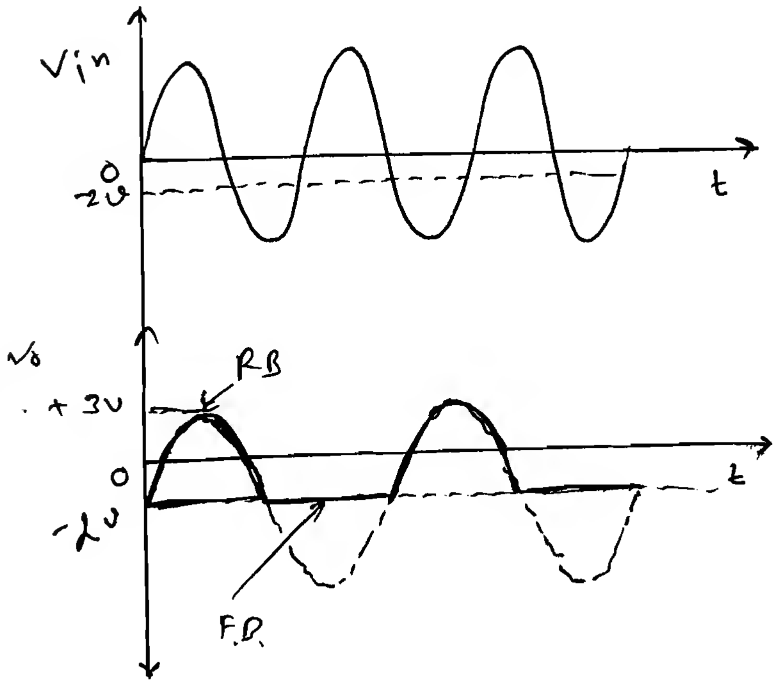
$-2 - V_{in} > 0$

$\boxed{V_{in} < -2V} \rightarrow$ F.B

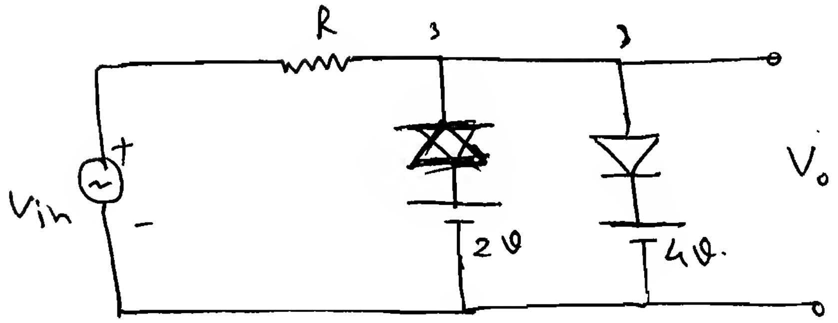
$\boxed{V_o = -2V}$

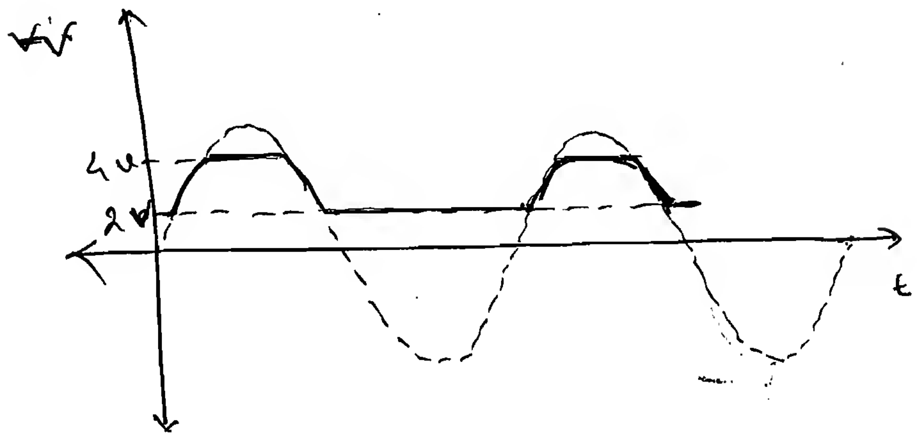
$V_{in} \geq -2V \rightarrow$ R.B.

$V_o = V_{in}$

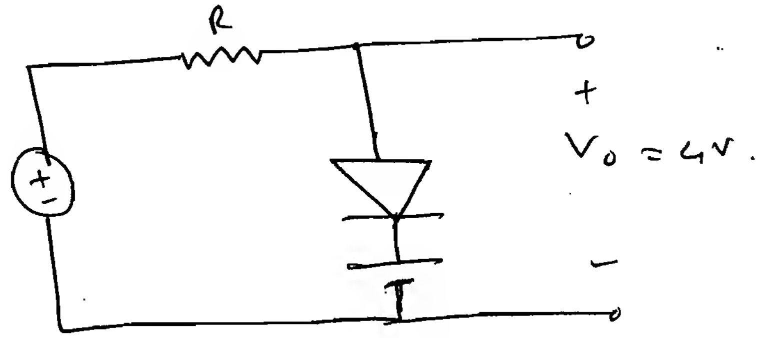


* Design a double bias clipper / slicer

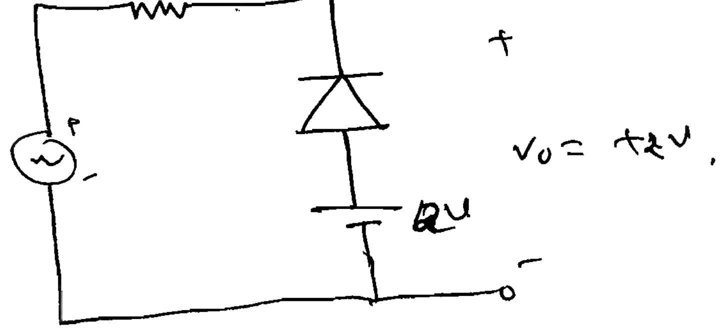




① case-1: $V_{in} > 4 \rightarrow V_o = +4V$.



② case-2: $V_{in} < 2 \rightarrow V_o = +2V$.



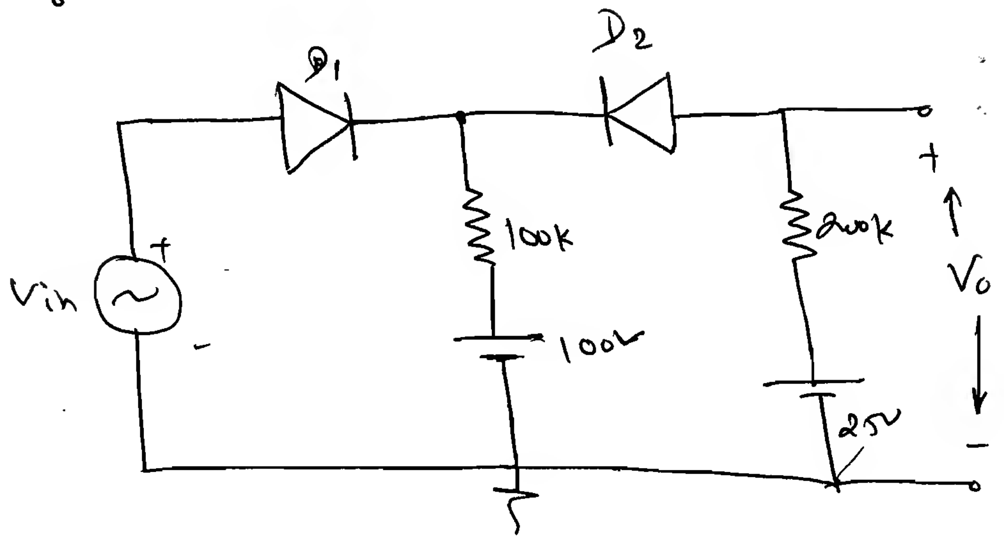
Case-3: $2 \leq V_{in} \leq 3$.

Both RB

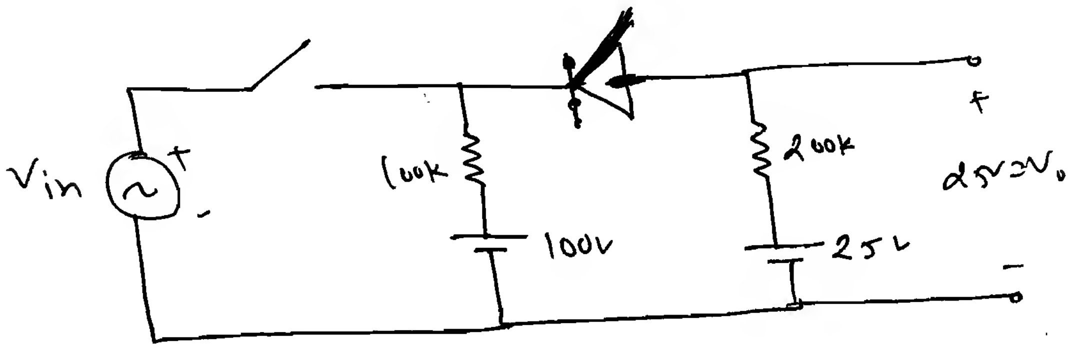
$V_o = V_{in}$.

* Sketch the Transfer Characteristics of i/p varies from 0 to 150 V.

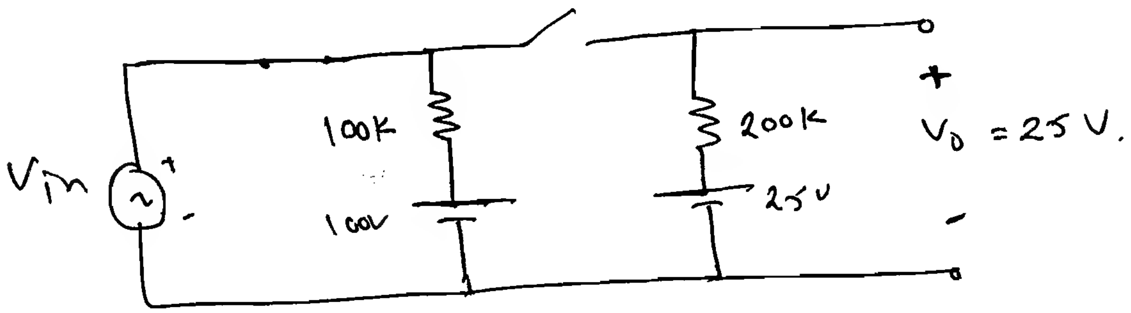
→

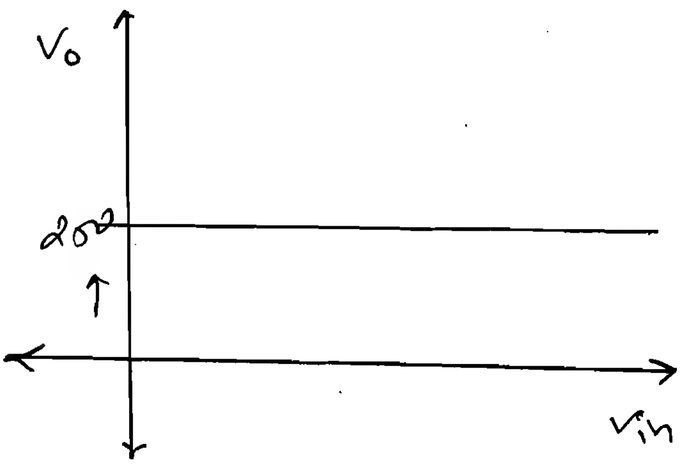


→ Case: (1) $V_{in} = 0V$, so D_1 & D_2 off.



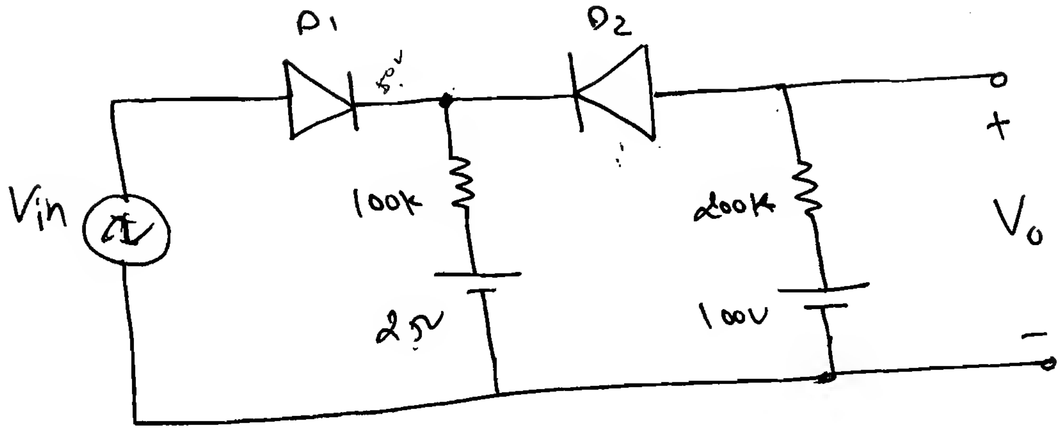
Case - (2) $V_{in} \geq 100V$



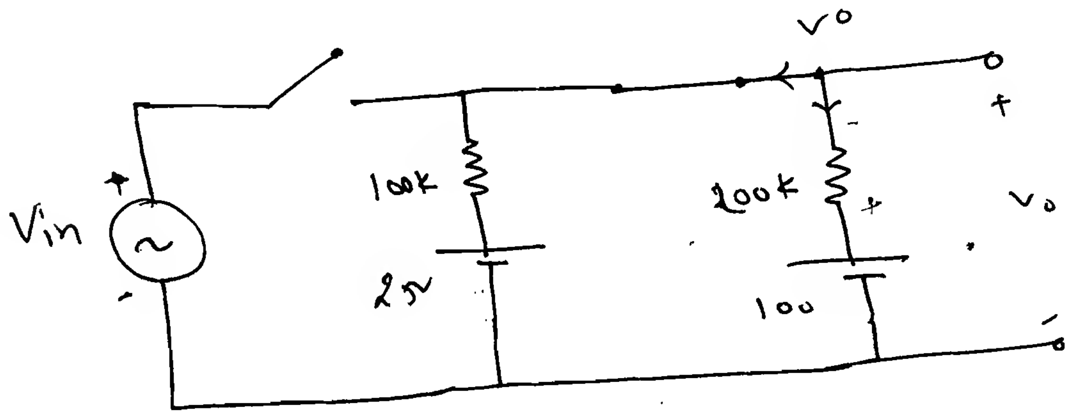


Transfer Characteristic.

* Sketch transfer Chars.



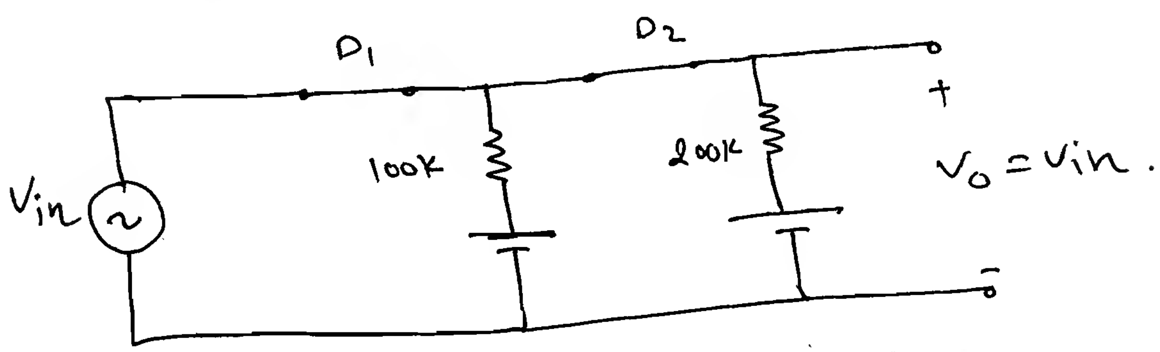
→ Case (i): $V_{in} = 0$, $D_1 = \text{off}$, $D_2 = \text{ON}$.



KCL, $\dfrac{V_o - 25}{100} + \dfrac{V_o - 100}{200} = 0$

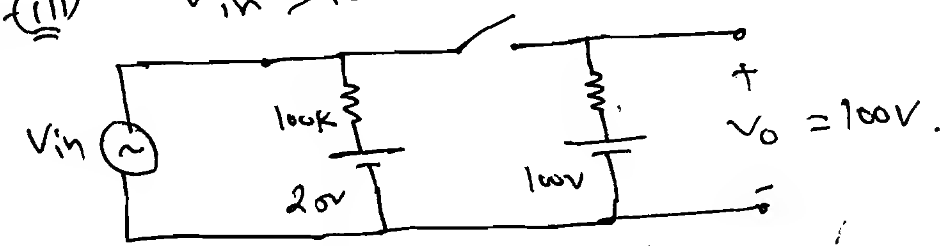
$\therefore \boxed{V_o = 50\,V}$

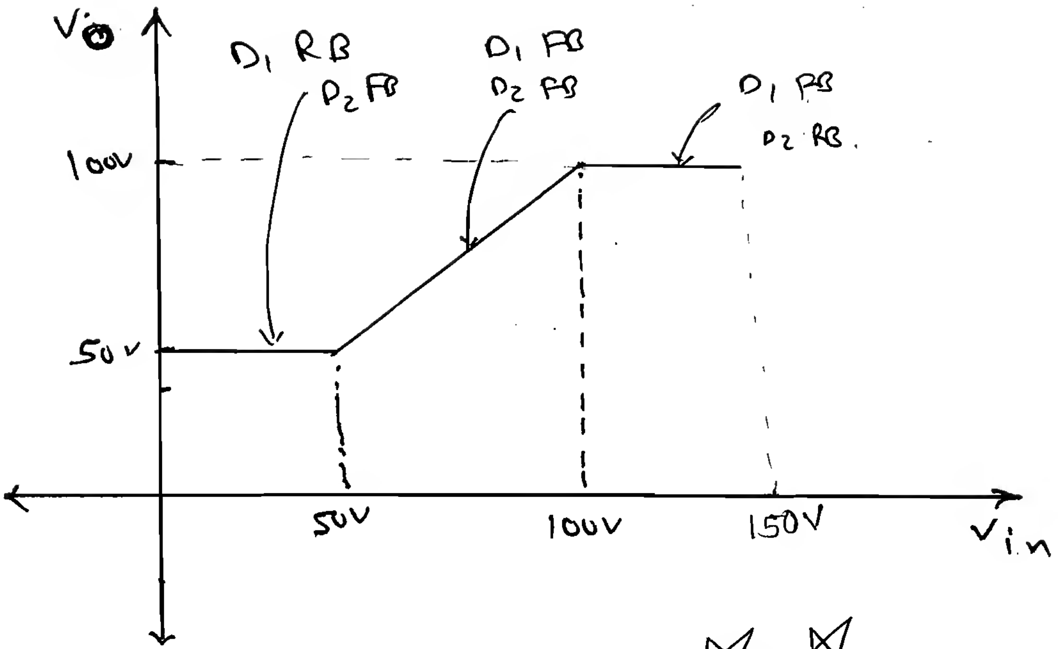
→ Case (ii) $100V \geq V_{in} > 50V$. $D_1 = \text{ON}$, $D_2 = \text{ON}$.



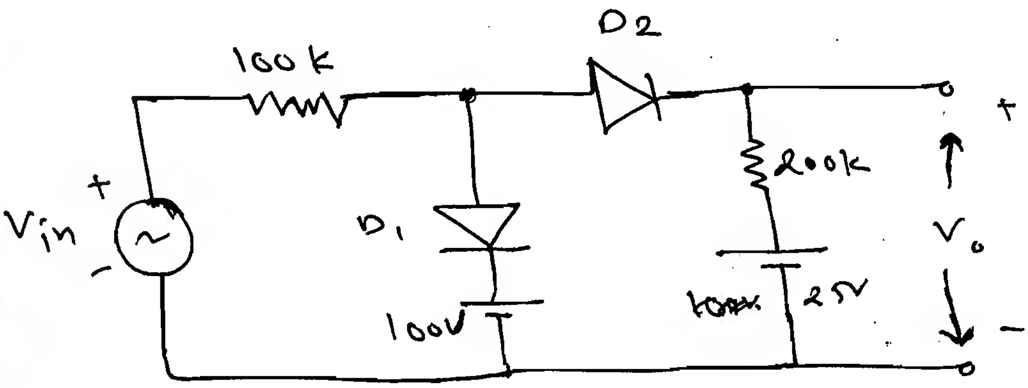
$V_o = V_{in}$.

→ Case (iii) $V_{in} > 100V$.

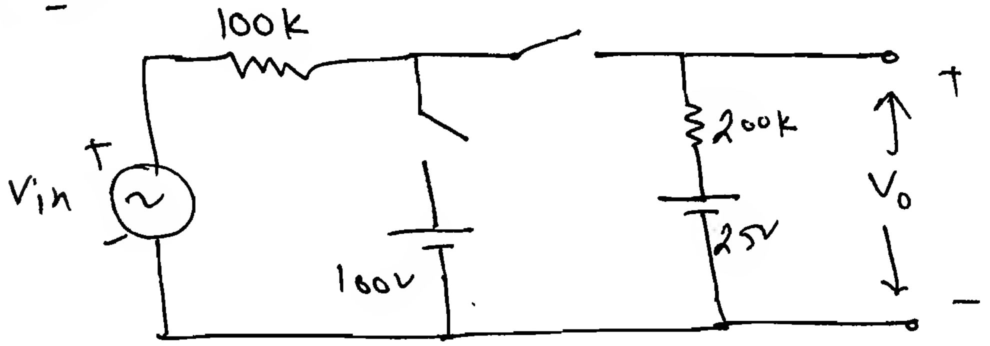




* **Sketch transfer char:**

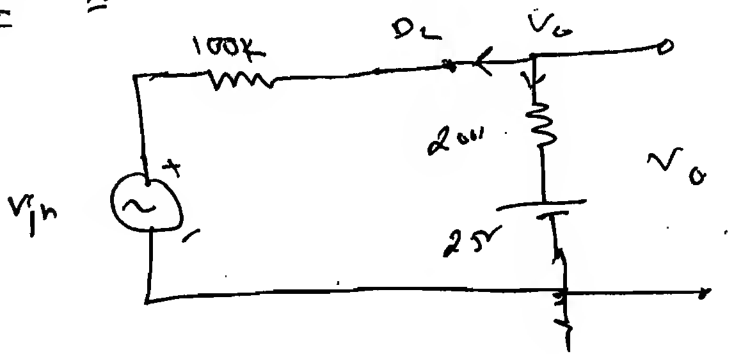


Case-(i) $V_{in} = 0$. , $D_1 = OFF$, $D_1 = OFF$



$\boxed{V_o = 25V}$

Case-(ii) $V_{in} \geq 25V$. $D_1 = OFF$, $D_2 = ON$.



$$\therefore \frac{V_o - V_{in}}{100} + \frac{V_o - 25}{200} = 0.$$

$$\therefore 2V_o - 2V_{in} + V_o - 25 = 0.$$

$$\therefore 3V_o = 2V_{in} + 25.$$

$$\therefore V_o = \frac{2}{3} V_{in} + \frac{25}{3}.$$

Now, max value of $V_o = 100\,V$.

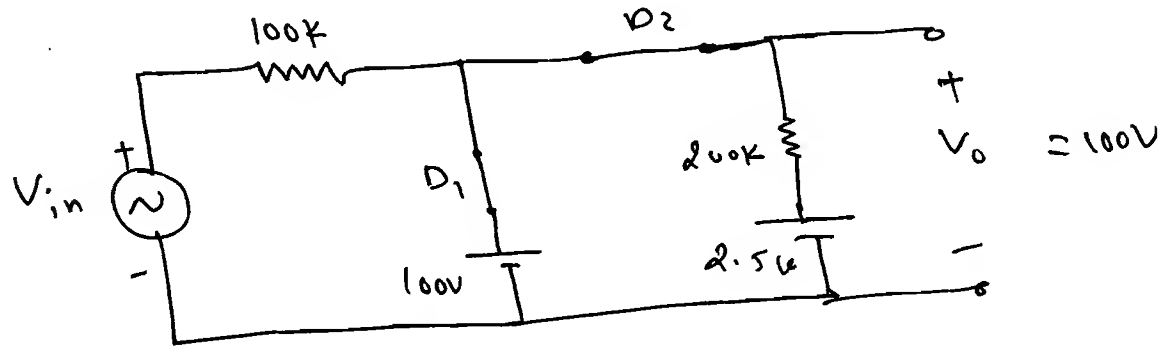
$$\therefore 100 = \frac{2}{3} V_{in} + \frac{25}{3}.$$

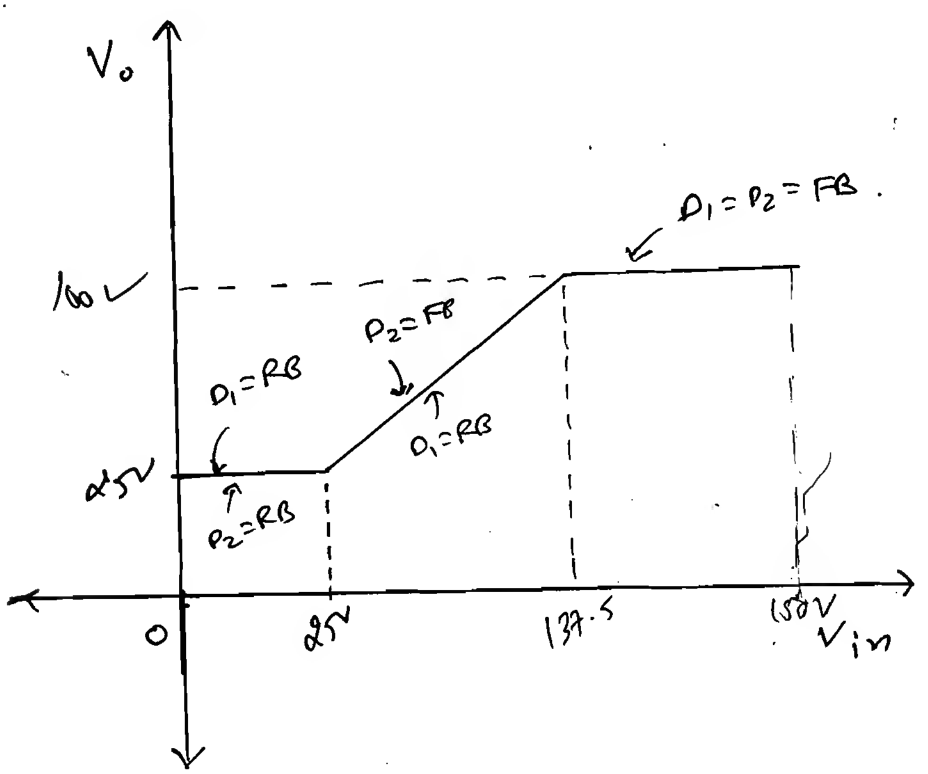
$$\therefore \frac{300 - 25}{2} = V_{in}$$

$$\therefore V_{in} = 137.5\,V. \Rightarrow V_o = 100V.$$

Case-(iii)

When $V_{in} > 137.5$. $D_1 = ON$, $D_2 = ON$.



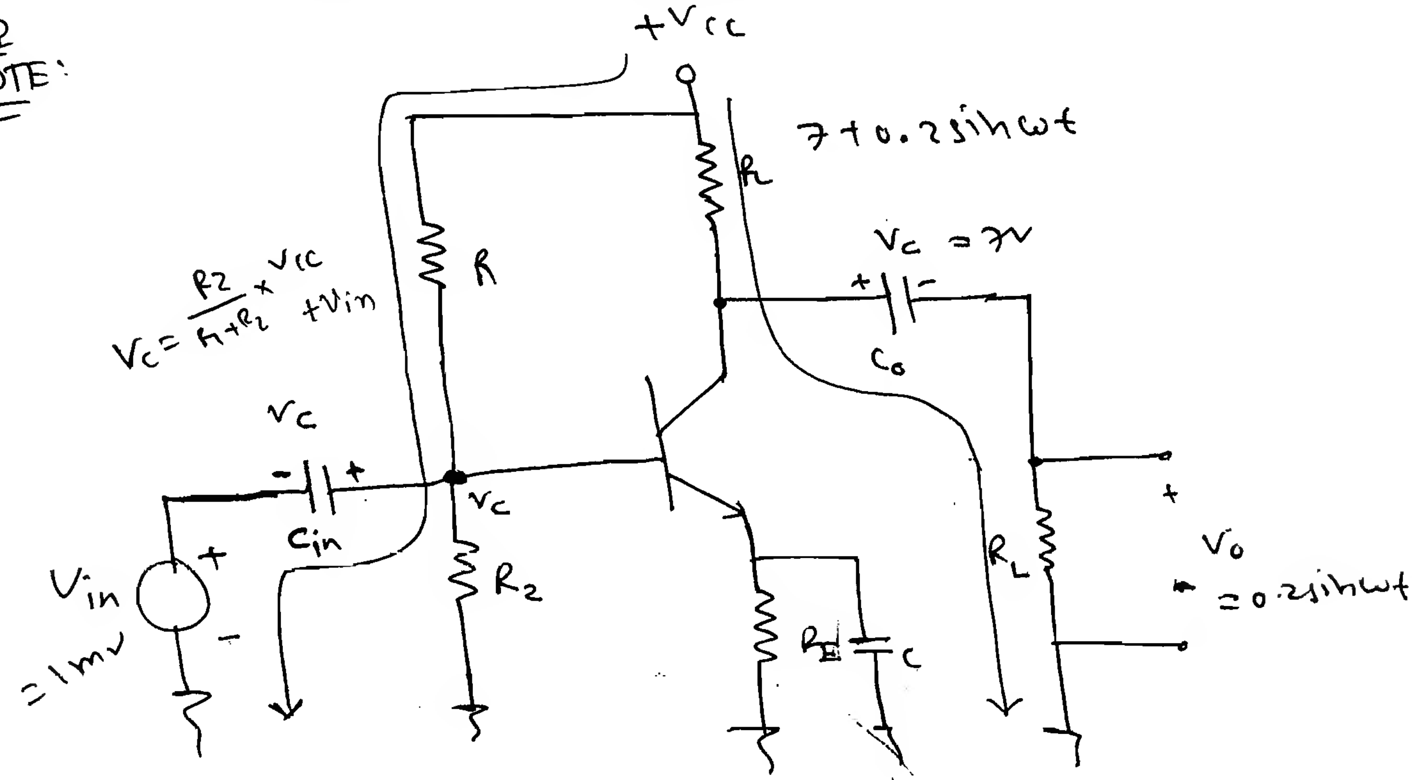


☆ Clamping circuits or Clampers:

→ Clamper is a circuits that Adds DC to the given input wave form.

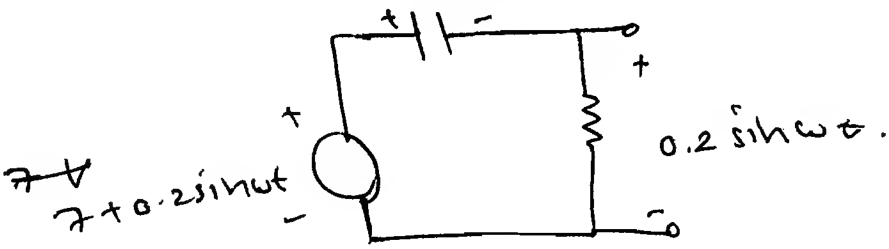
→ Also called DC Restorer.

Imp NOTE:



Clampper

→ ① for V_o.

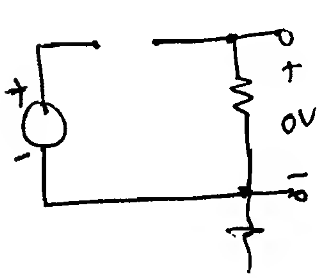


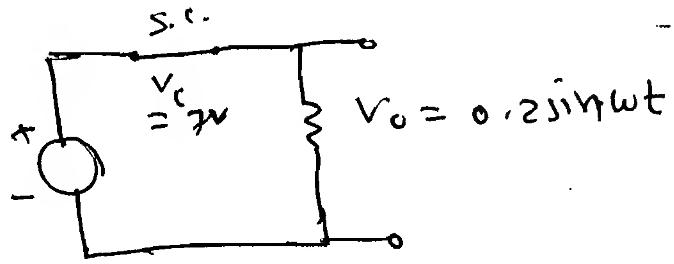
$$Z = \left|\frac{1}{\omega C}\right| \Omega$$

(D.C). $\omega = 0 \Rightarrow Z = \infty$
O.C.

(A.C) $\omega = \infty \Rightarrow Z = 0$
S.C.

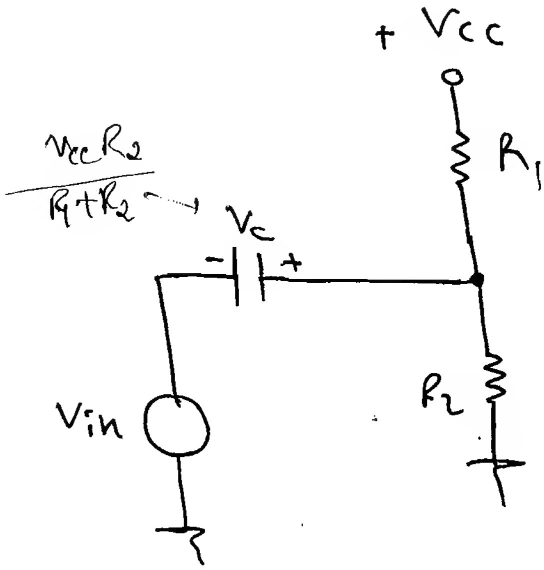
DC	AC
$\omega = 0$	$\omega = \infty$
$Z = \infty$	$Z = 0$
O.C.	S.C.





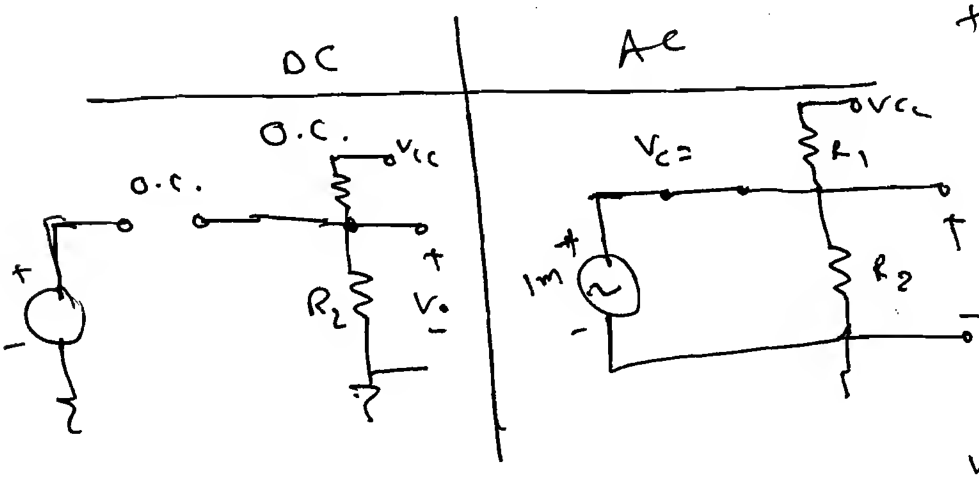
→ So, at o/p capacitor is used to block DC component and allow AC component.

② At i/p:



* If we don't use capacitor Ci then very small input voltage available and therefore the device is in cut off region.

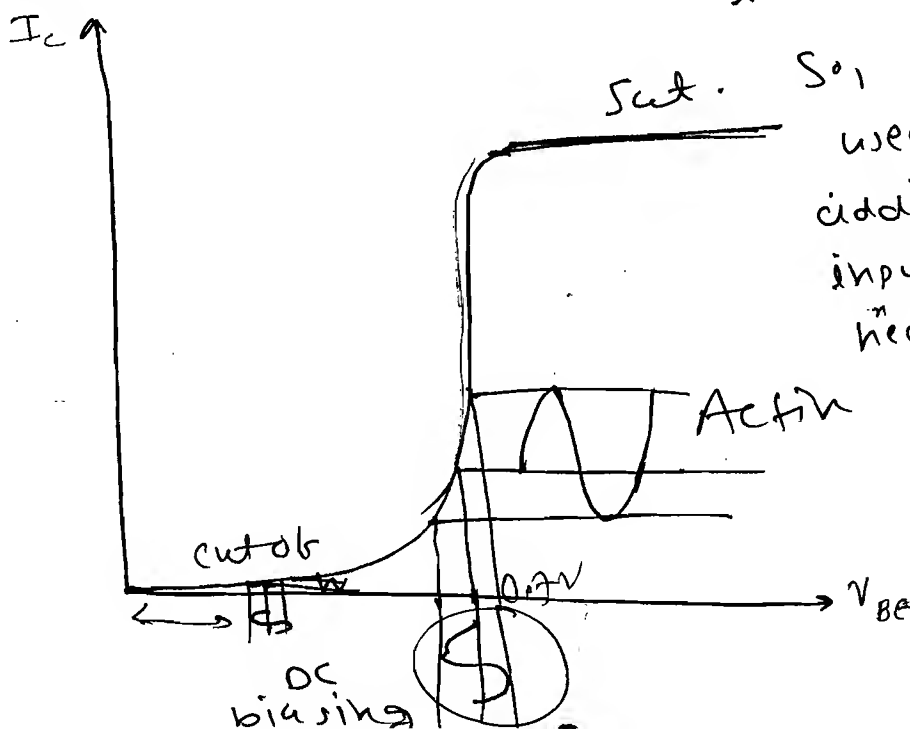
→ Now, because of capacitor it store the DC voltage and this DC voltage are used Add to the input so that DC biasing point shift from small value to large value so that the device will come into active region.



$V_{in} = V_{C_i} = V_0$.

$$\therefore V_0 = \frac{R_2}{R_1+R_2} \times V_{cc}$$

Biasing: Adding some DC.



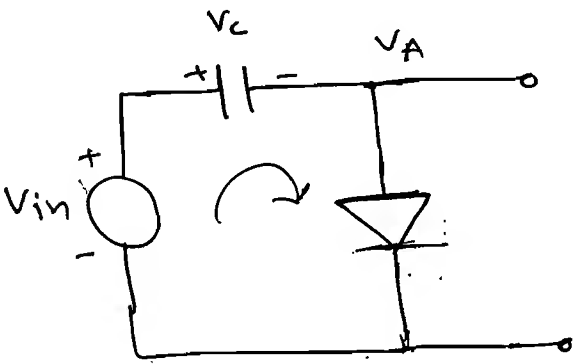
So, capacitor is used for the adding dc to input and here act as clamper.

★ **Two simple steps to draw the clamped output:**

(i) Find the capacitor voltage V_c in its steady state.

(ii) Replace diode with open switch and draw the output waveform.

Ex-1

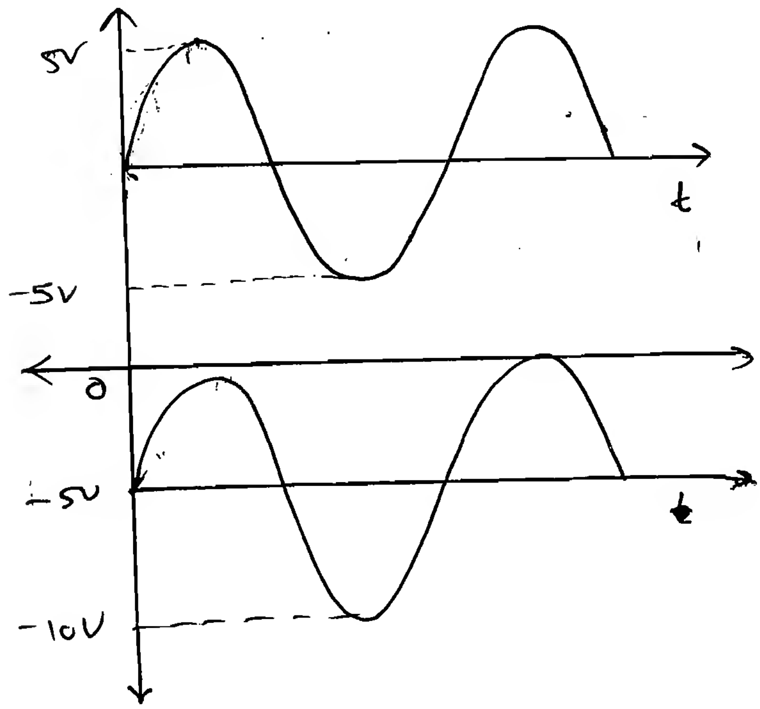


$V_A = V_{in} - V_c$

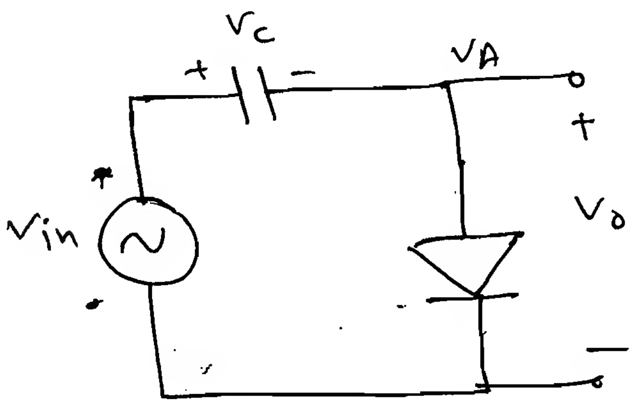
$V_A = V_{in} - 5$ $\quad V_c = +5V.$

V_{in} range: -5 to $+5$

V_A range: -10 to $0V$. (neg).



Ex-2

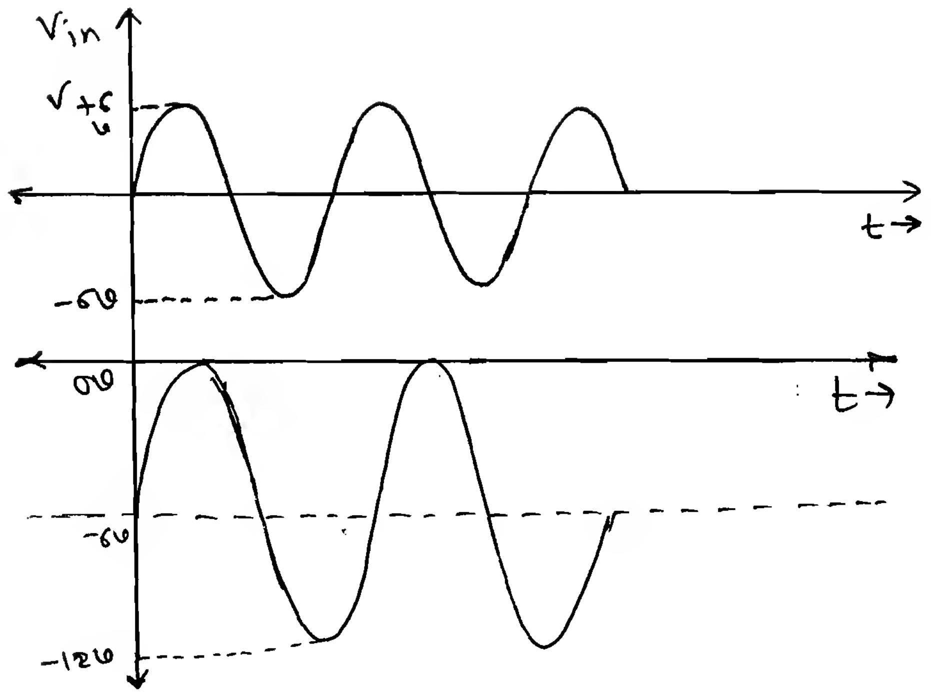


$V_c = 6V$

$V_A = V_{in} - 6$,

V_{in} range: -6 to $+6V$.

$\therefore$ V_o range: -12 to $0V$.



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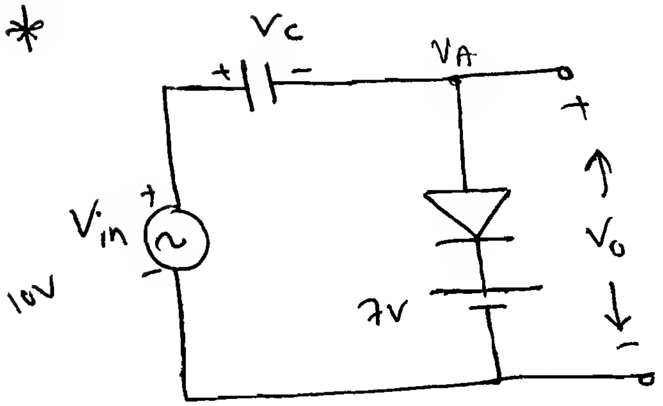


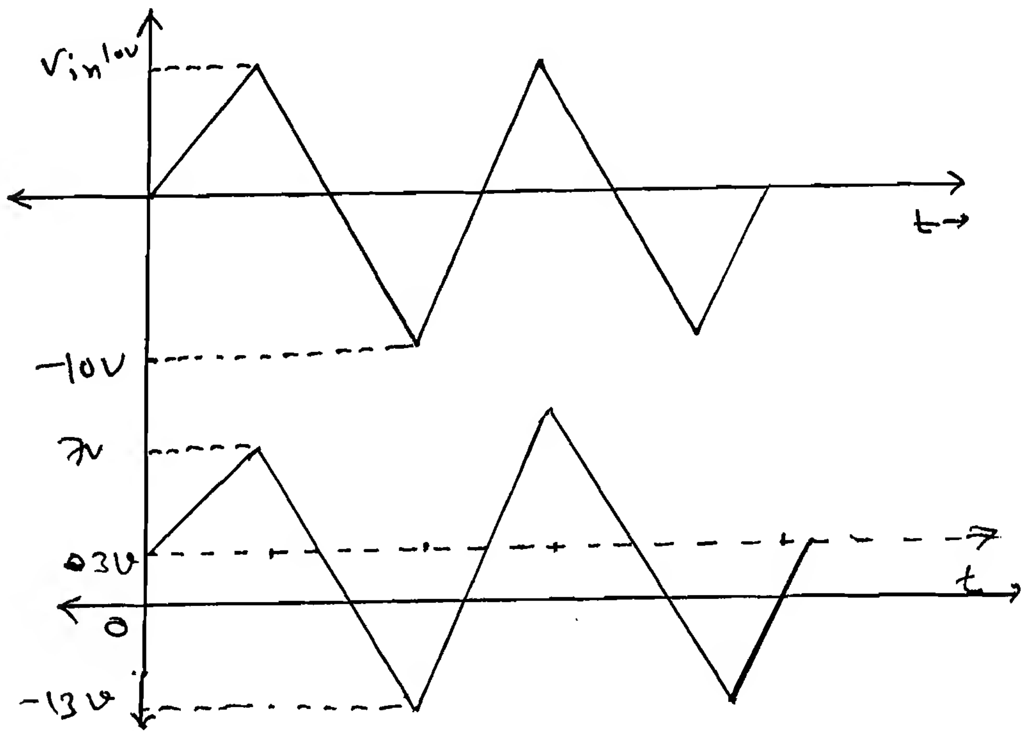
$10 - V_c - 7 = 0$

$\boxed{V_c = 3V}$

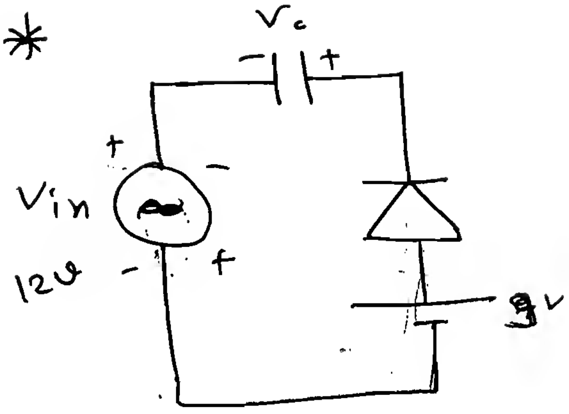
Vin Reng: −5 to +5.

$V_o = V_{in} - 3\,v$.

V_o range: 7 to −13v.



*



$V_{in} + V_c - 7 = 0.$

$\therefore$ ~~Vin/7~~

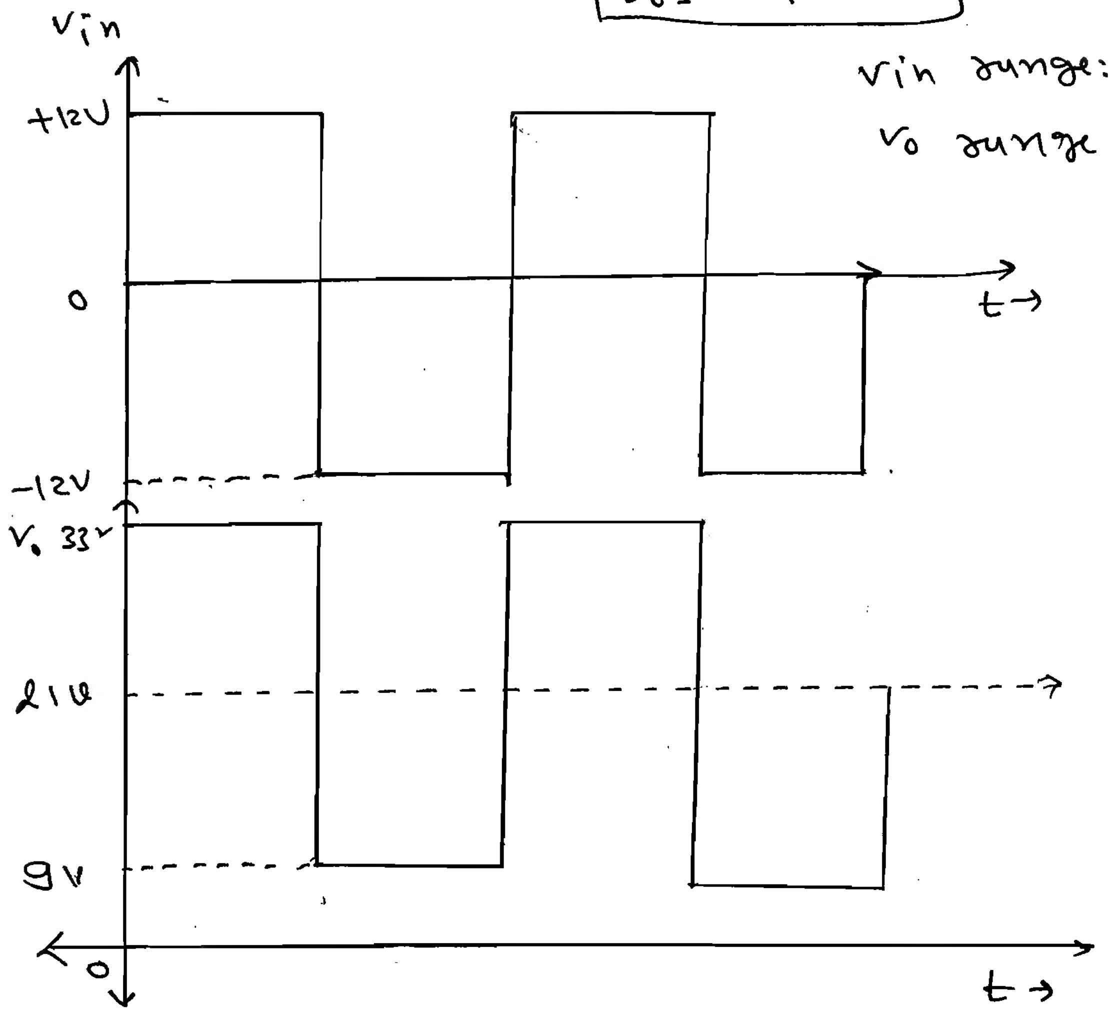
$\therefore$ ~~+12~~

$-12 + V_c - 9 = 0$

$\boxed{V_c = 21V}$

$V_0 = V_{in} + V_c$

$\boxed{V_0 = V_{in} + 21.}$



Vin range: −12 to 12

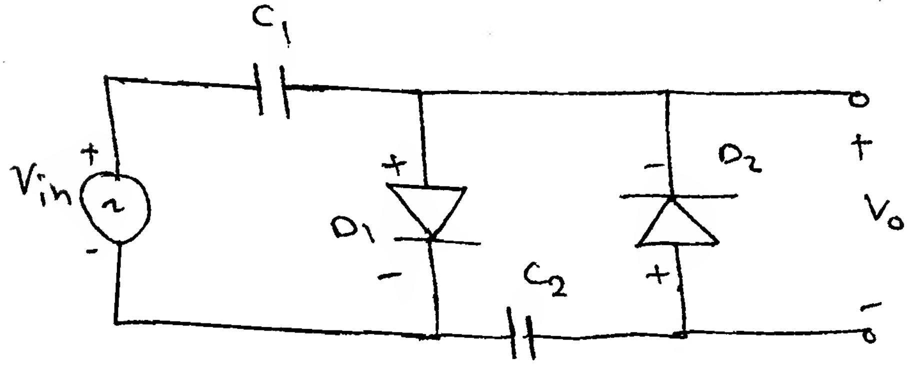
V₀ range: 9 to 33.

☆ Voltage Mutiplier:

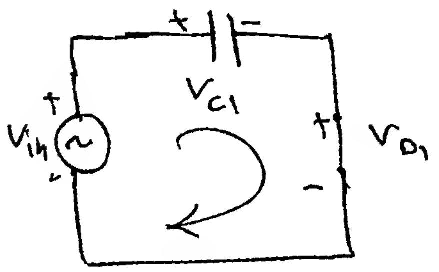
→ $V_{in} = V_m \sin \omega t$ (AC)

$V_o = n V_m$ (DC) $n = 2, 3, 4, \ldots$

* Doubler:



⇒ During +ve cycle



$\therefore V_{in} - V_{c1} = 0\,V$

$\therefore \boxed{V_{C1} = 6V}$

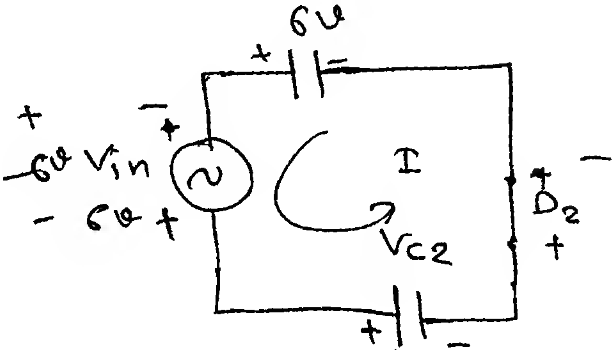
$\therefore V_{in} - 6V - V_{D1} = 0$. [when V_{D1} is R.B]

$\therefore \boxed{V_{D1} = V_{in} - 6\ V}$

V_{in} range: -6 to $+6$

V_{D1} range: -12 to $0\,V$

⇒ During -ve cycle.



$\therefore V_{in} - V_{c2} + 6 = 0$

$V_{c2} = V_{in} + 6$.

$\therefore V_{c2} = 6 + 6 = 12V$.

$\boxed{V_{C2} = 12V}$

$\therefore V_{in} - 6 + V_{D2} + V_{C2} = 0$

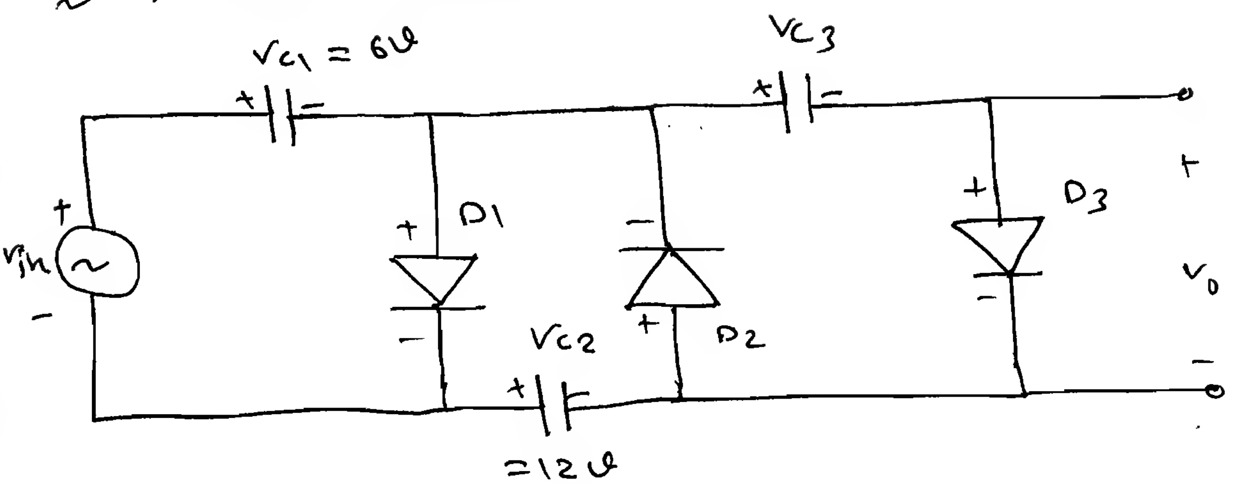
$\therefore V_{in} - 6 + V_{D2} + 12 = 0$

$\therefore \boxed{V_{D2} = -(V_{in} + 6)\ V}$

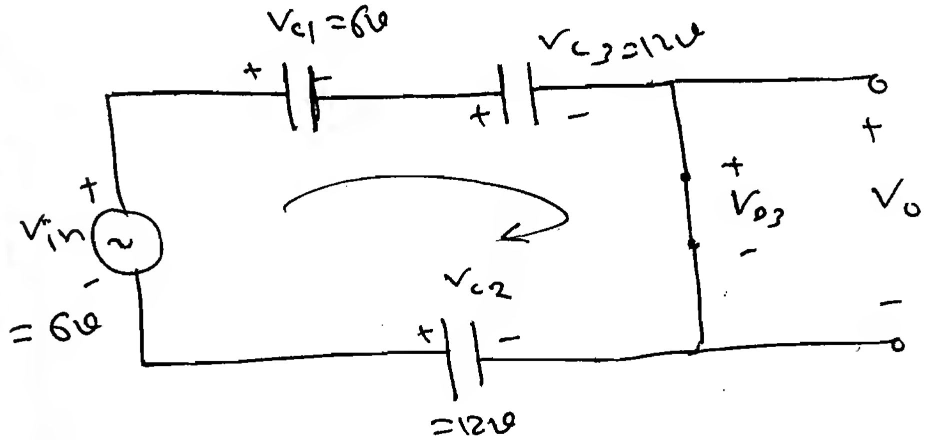
V_{in} range: -6 to $+6V$

V_{D2} range: 0 to $-12V$.

* Voltage tripler:



→ Now again in second positive cycle,



$\therefore \quad V_{in} - 6 - V_{C3} + V_{C2} = 0$

$\therefore \quad 6 - 6 - V_{C3} + 12 = 0.$

$\therefore \quad \boxed{V_{C3} = 12V}$

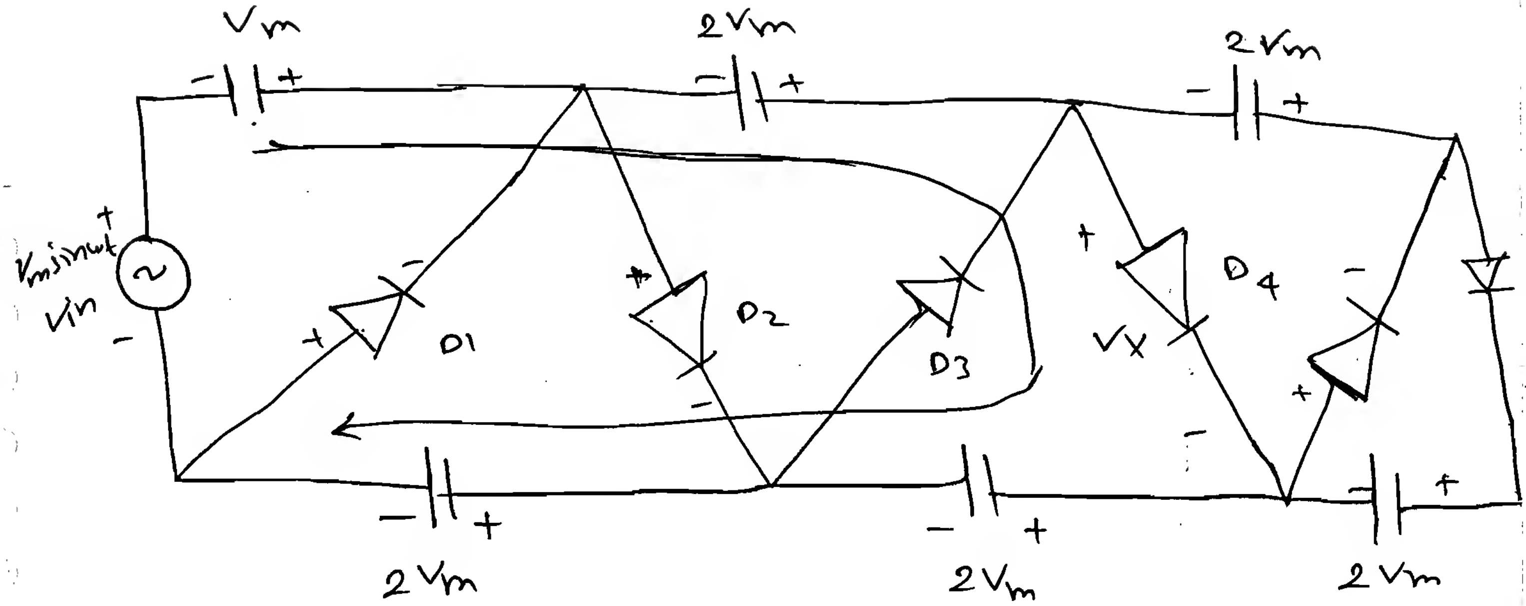
$\therefore \quad V_{in} - V_{C1} - V_{C3} + V_{D3} + V_{C2} = 0.$

$\therefore \quad V_{in} - 6 - 12V + V_{D3} + 12V = 0.$

$\therefore \quad \boxed{V_{D3} = V_{in} - 6V}$

So, Capacitor can charge up to only voltage range of input.

*

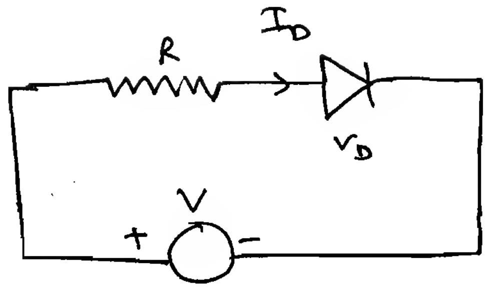


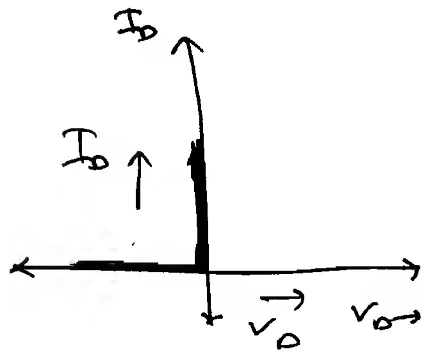
$\therefore \quad V_{in} + V_m + \cancel{2V_m} - V_x - \cancel{2V_m} - 2V_m = 0$

$\therefore \quad \boxed{V_x = V_{in} - V_m.}$

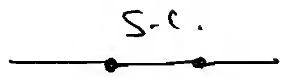
D: 09/07/2013

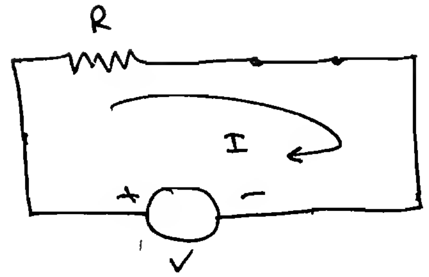
*



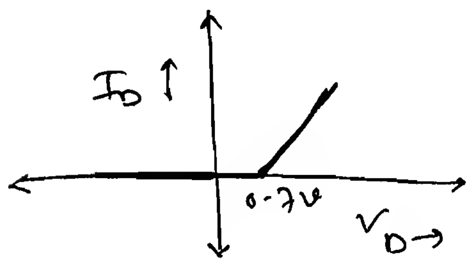


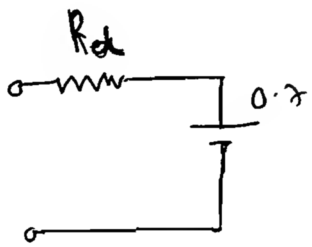
Model

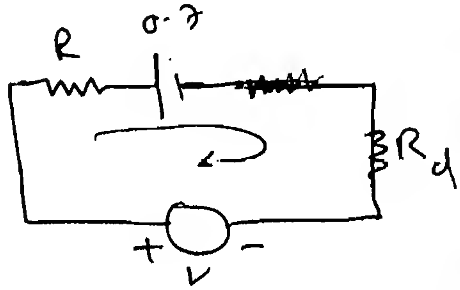




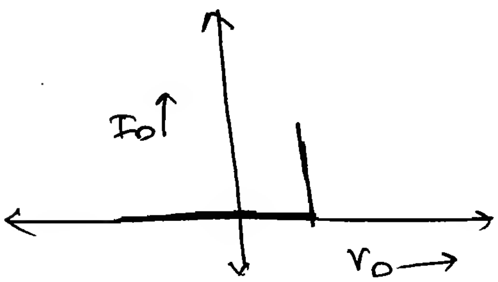
$I = V/R.$

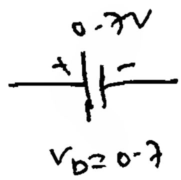


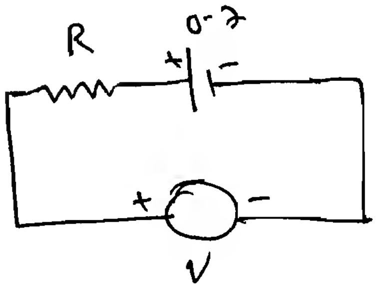




$$I = \frac{V - 0.7}{R + R_d}.$$



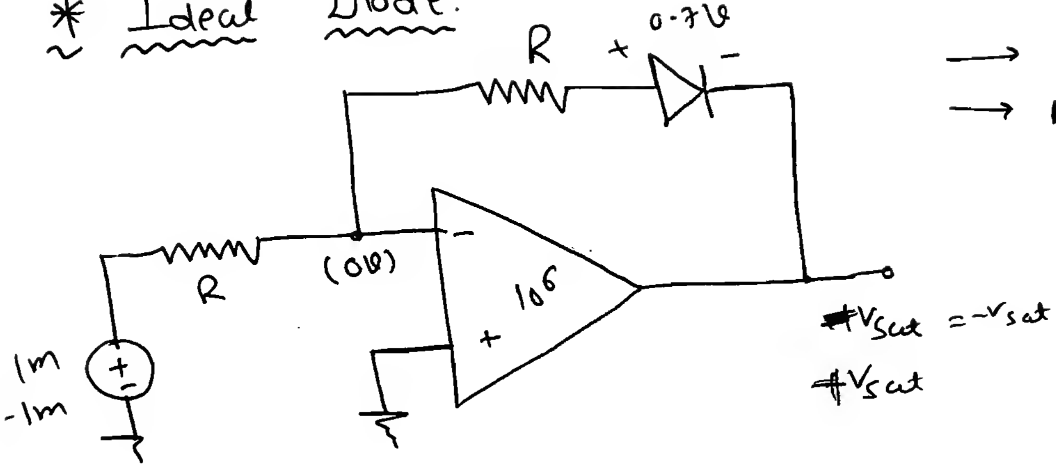


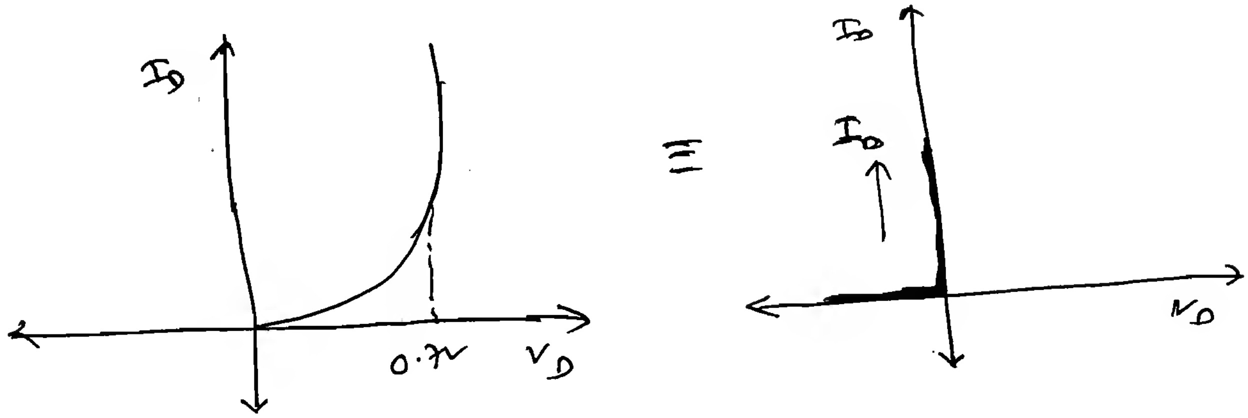


$$I = \frac{V - 0.7}{R}.$$

* Ideal Diode:

→ Super diode
→ Precision diode.





→ When diode is F.B. the OP-Amp is in close loop configuration.

→ But at initial stage input voltage is very small and so diode is off for a very small time. and so OP-Amp is is in open loop configuration. so

O/P is $V_o = A V_d$

$\therefore V_o = 10^6 \times (1mV) \approx 1000V.$

But, V_o never exceed $\pm V_{sat}$ so.

$\therefore V_o = -V_{sat}$ ($\because$ inverting amp.).

Now, this $-V_{sat}$ make diode F.B. and OP-Amp is now in close loop configuration.

→ so, within a no time. diode will be in F.B. condition i.e. $\frac{0.7}{10^6}$ V required to turn on the diode instead of 0.7 V.

So, for 1 mV, diode will be on and it is look like a ideal diode. as shown in figure.

Note:

→ Virtual ground concept apply only when ~~open~~ op-Amp is in its negative close loop (negative feedback) configuration.

→ When the diode is on then apply virtual ground concept.

→ When the diode is off i.e O.C then op-Amp is in open loop op-Amp.

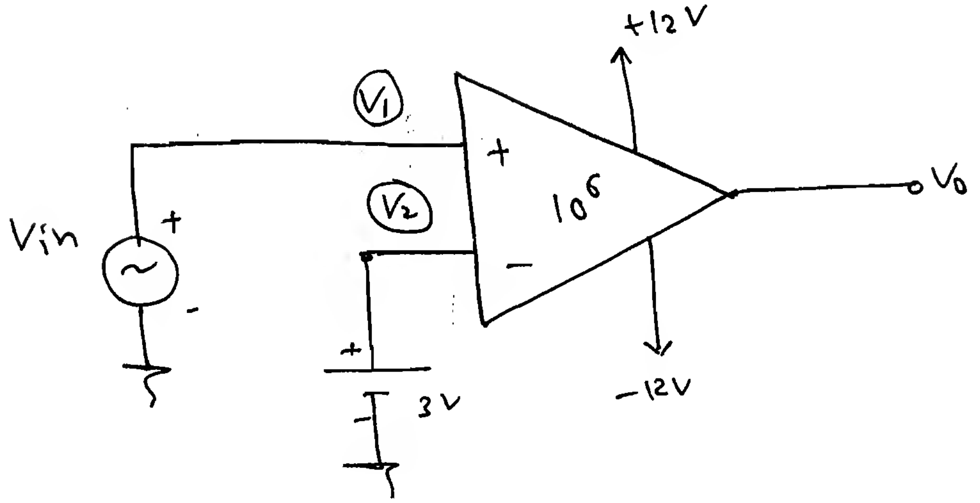
→ ~~When~~ Can not apply virtual ground concept in +ve feedback also.

→ When diode or BJT are driven by op-Amp then chara is changing to ideal diode.

→ Diode and BJT can be driven by op-Amp.

→ op-Amp is driver.

* Open loop configuration: (comparator).



→ $V_0 = A\,[V_1 - V_2]$.

$\therefore V_0 = A\,[V_{in} - 3]$.

Case-(i) when $V_{in} > 3 \Rightarrow V_{in} - 3$ is positive.

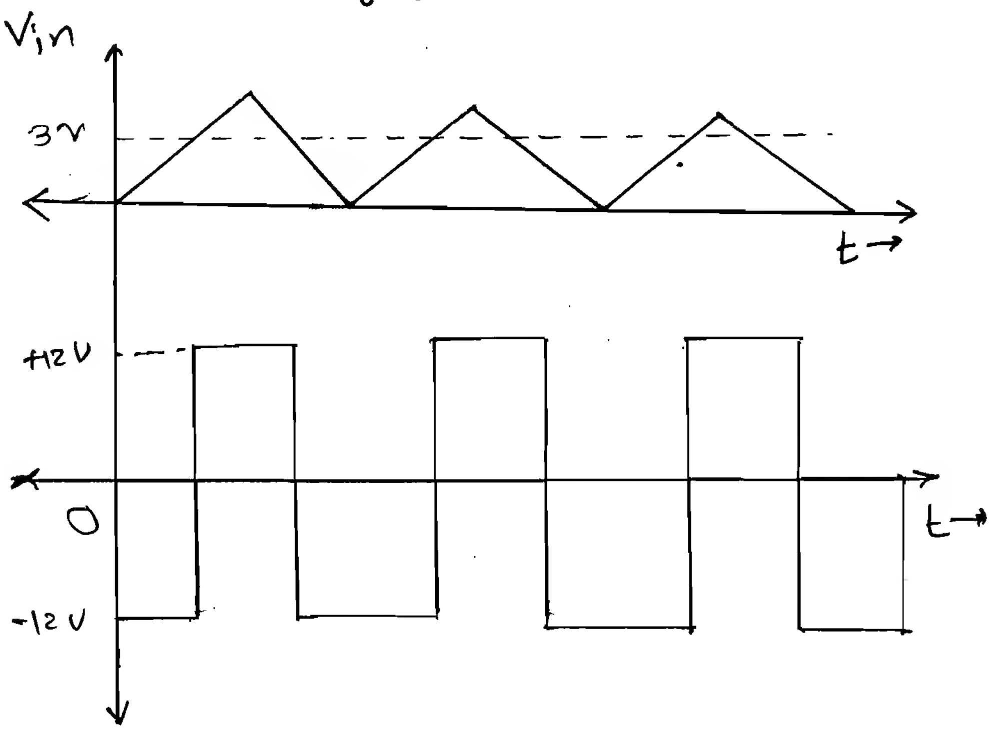
→ $V_0 = 10^6$ [small pos].

$V_0 = +V_{sat} = +12V$.

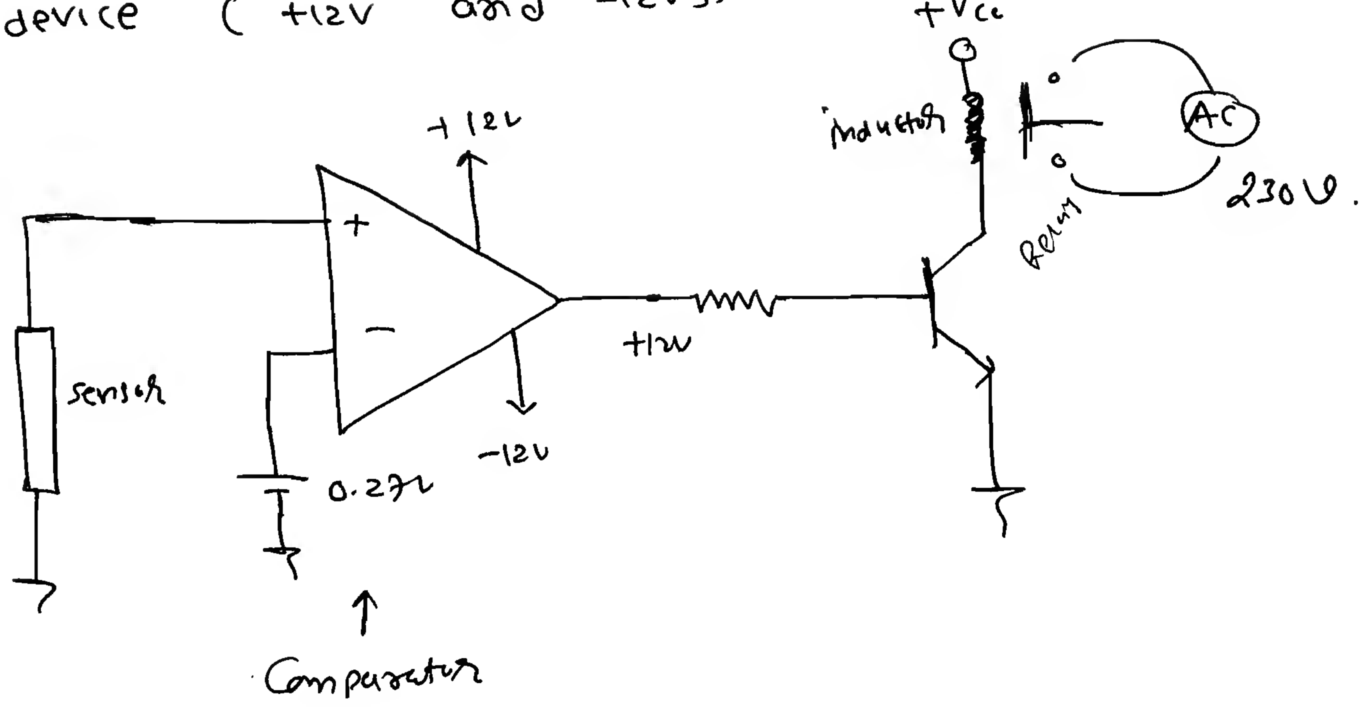
Case-(ii) When $V_{in} < 3 \Rightarrow V_{in} - 3$ is negative

→ $V_0 = 10^6$ [small neg]

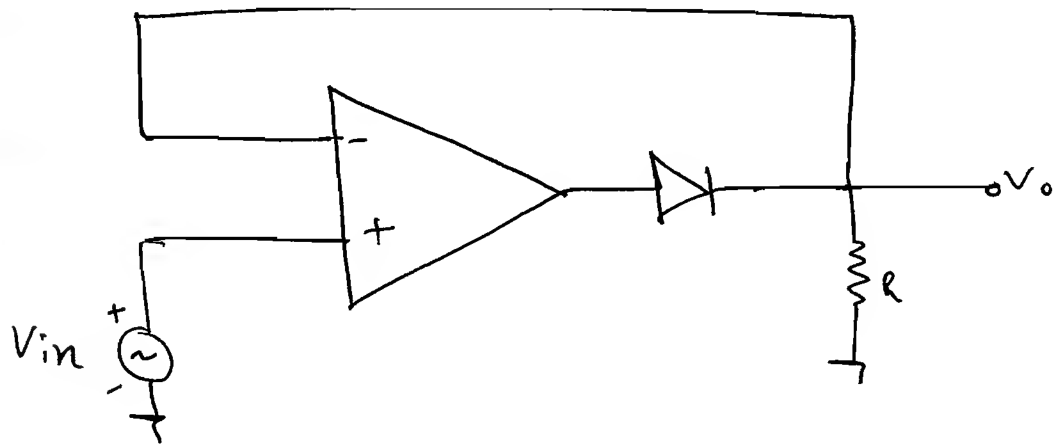
$V_0 = -V_{sat} = -12V$.



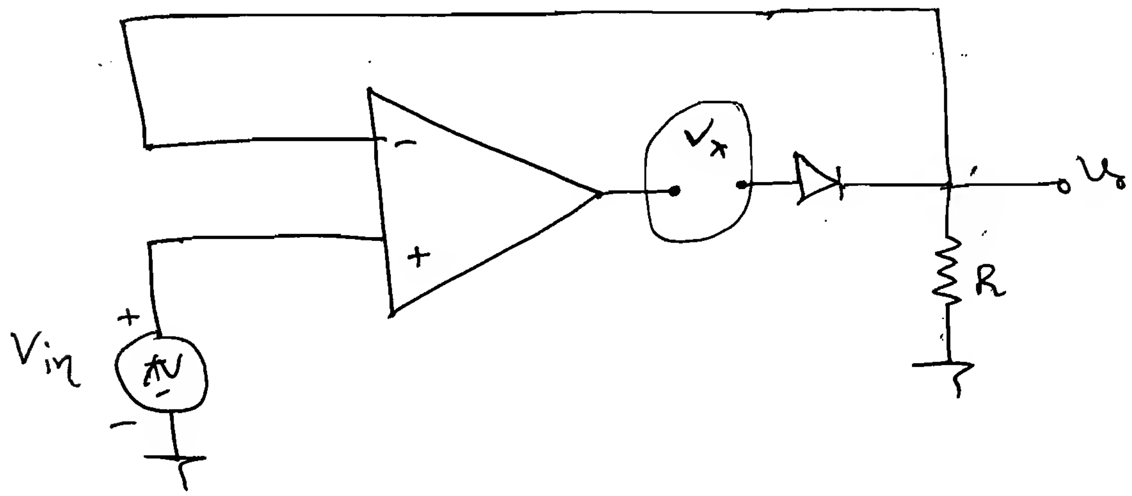
→ it is used for switching purpose for external device (+12V and -12V).



* Precesion diode (Ideal Diode).



|||



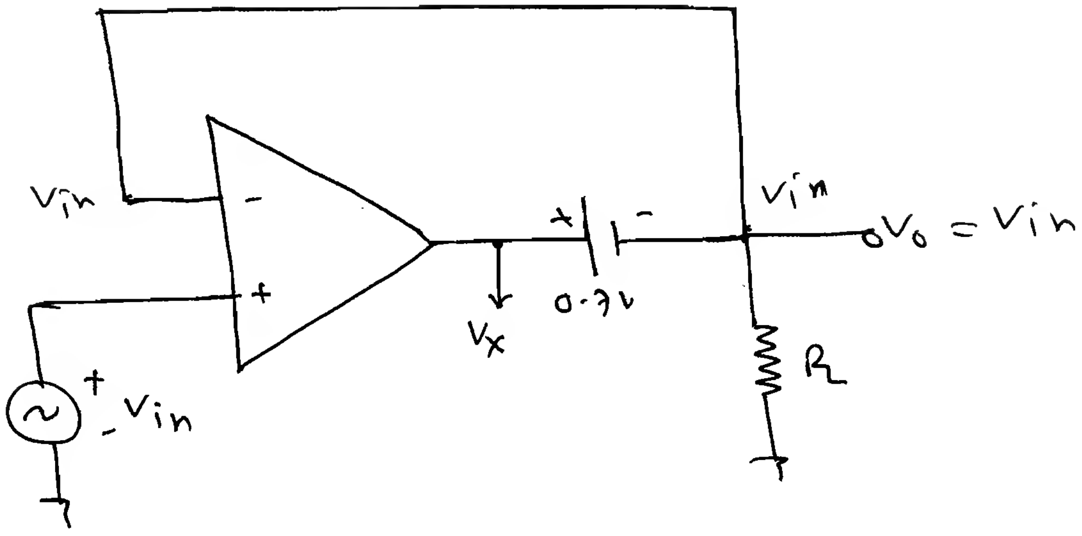
Case-1 When $V_{in} > 0 \Rightarrow V_x$ is pos.

$\Downarrow$

Diode is F.B. (Neg. F/B).

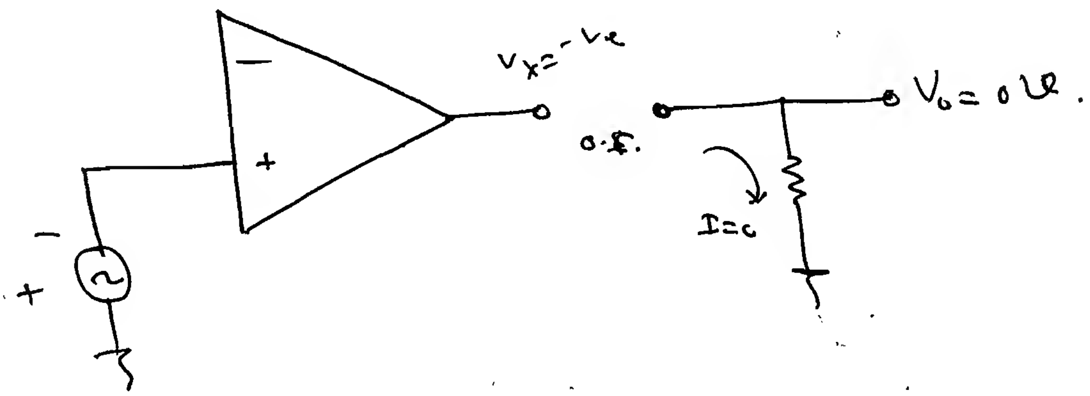
Vo=Vin even if vin=1µV

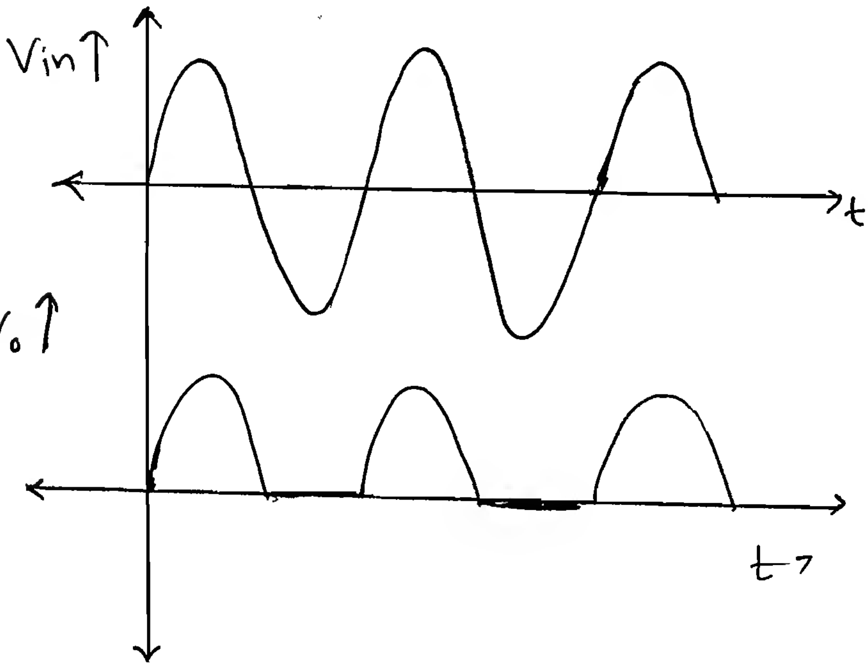
$V_{in} = \frac{0.7}{10^6} = 1\mu V$



$V_x = V_{in} + 0.7.$

Case-(ii) $V_{in} < 0 \rightarrow V_x$ is neg $\rightarrow$ Diode is R.B.

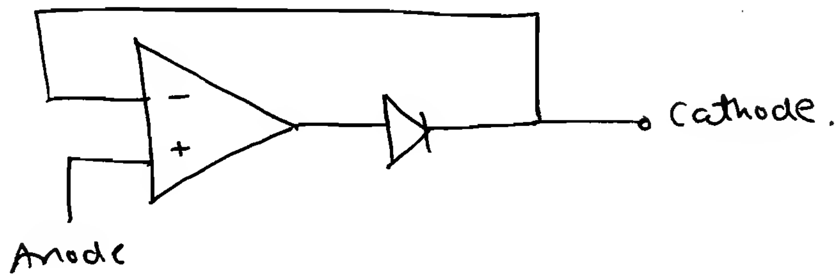




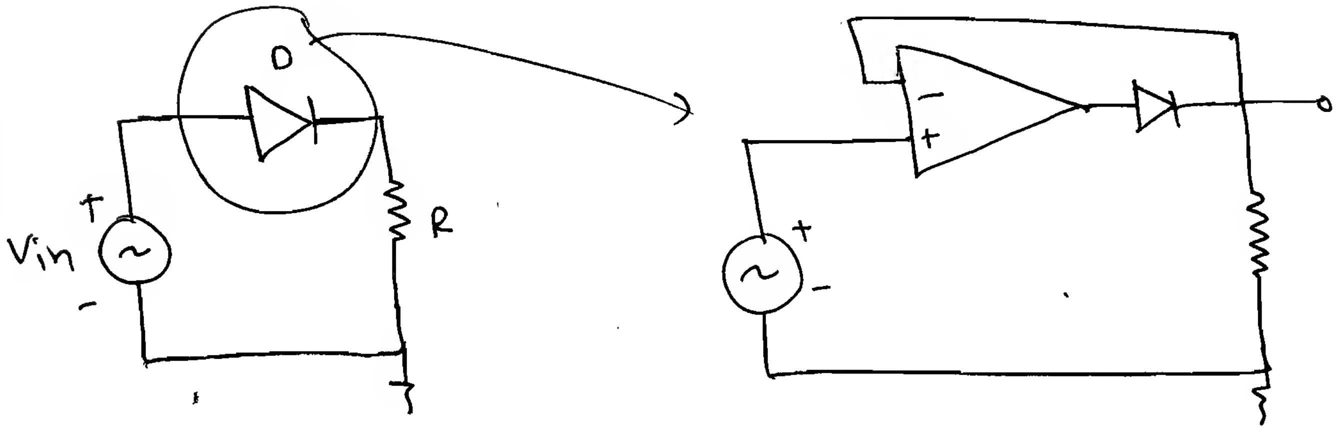
Half wave Rectifier.

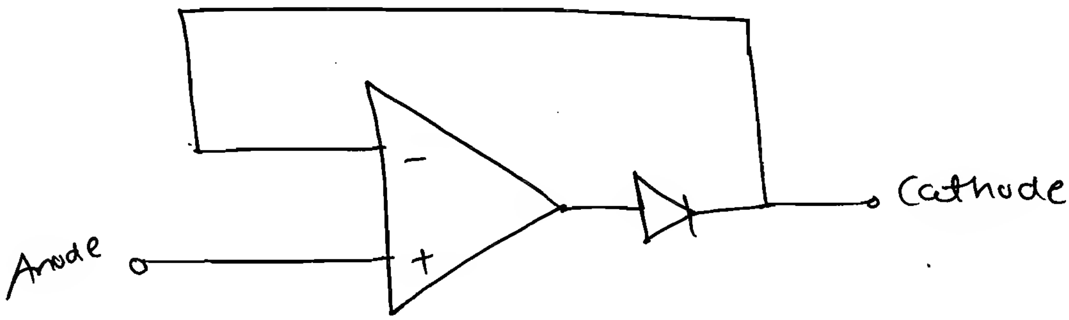
NOTE: This circuit rectifies all voltage V_{in} slightly greater than $\frac{0.7}{A_{OL}} \simeq \frac{0.7}{10^5} \cong 1\mu V$.

*



(ideal diode)

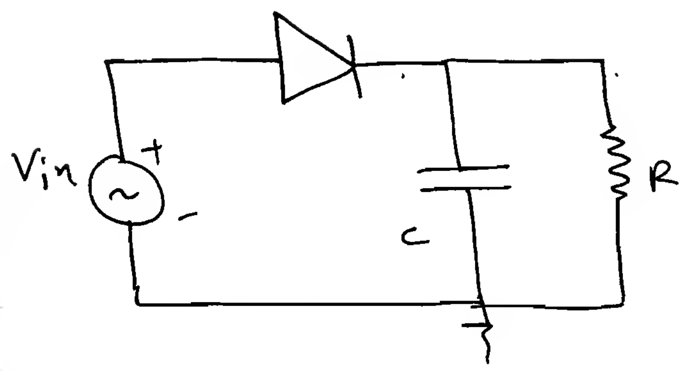




Ideal diode = op-amp + Diode.

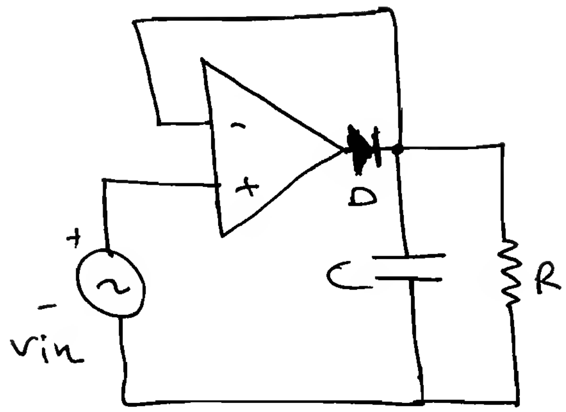
* Peak detector (envelope detector)

→ All Buffers have current gain.

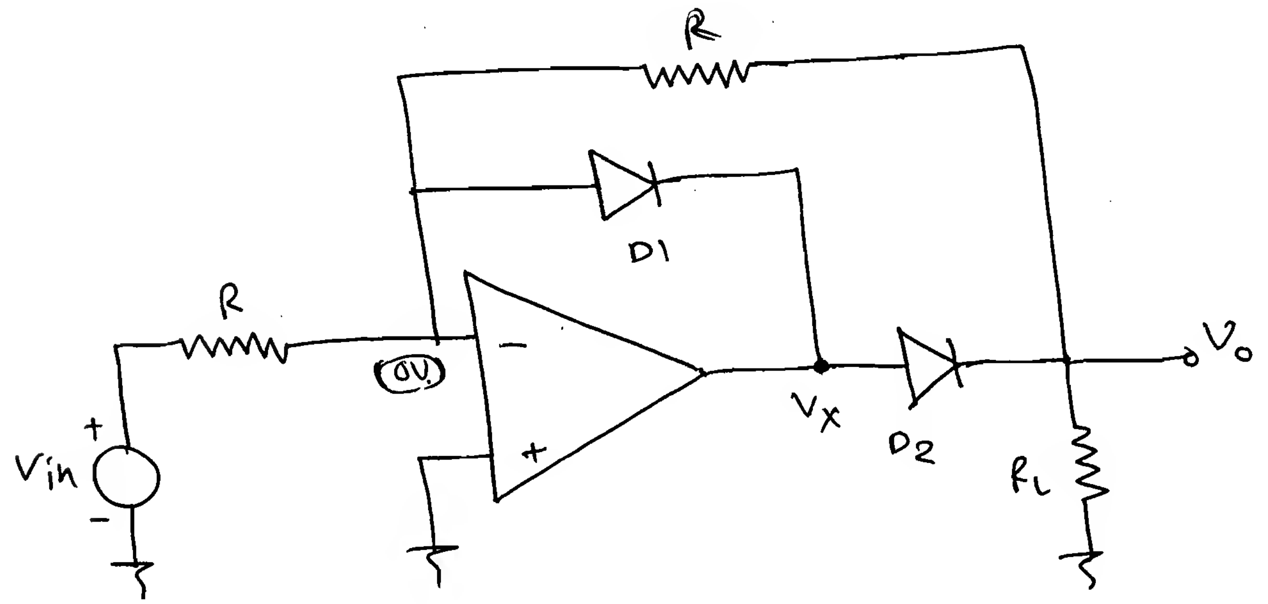


it wait till 0.7V

≡



* Improved Half Wave Rectifier:



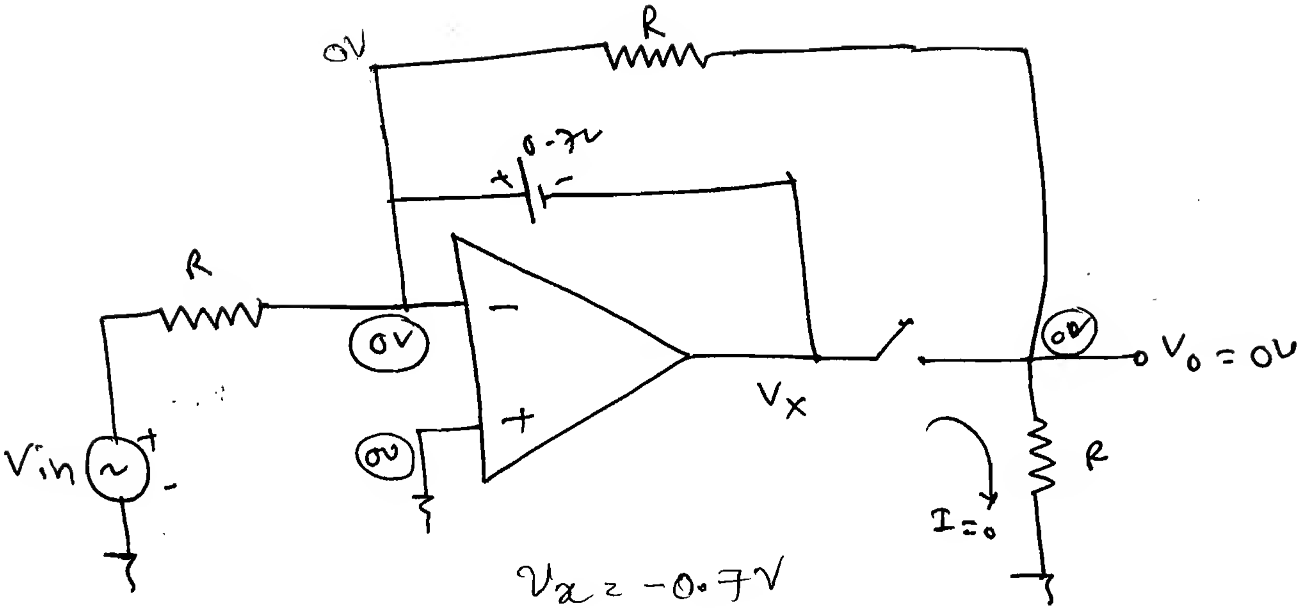
Case-(1):

When $v_{in} = +ve$

$v_x = -ve$.

So, $D_1 \rightarrow$ F.B.

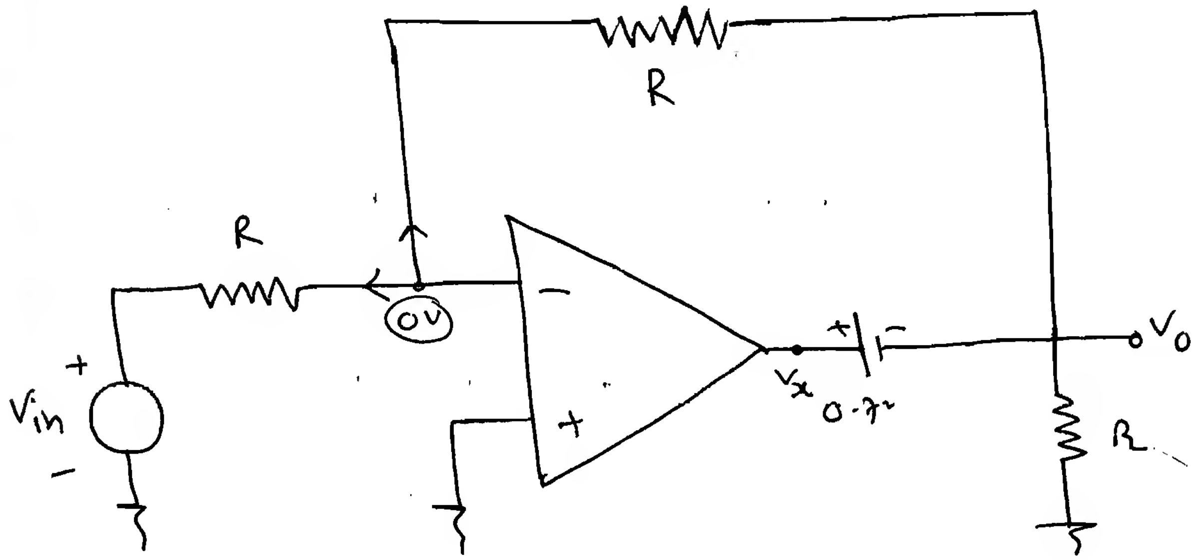
$D_2 \rightarrow$ R.B.



$V_x = -0.7V$

Case - 2

$$\left.\begin{array}{l} V_{in} \Rightarrow -ve \\ V_x \Rightarrow +ve \end{array}\right\} \begin{array}{l} D_1 \ RB \\ D_2 \ FB \end{array}$$

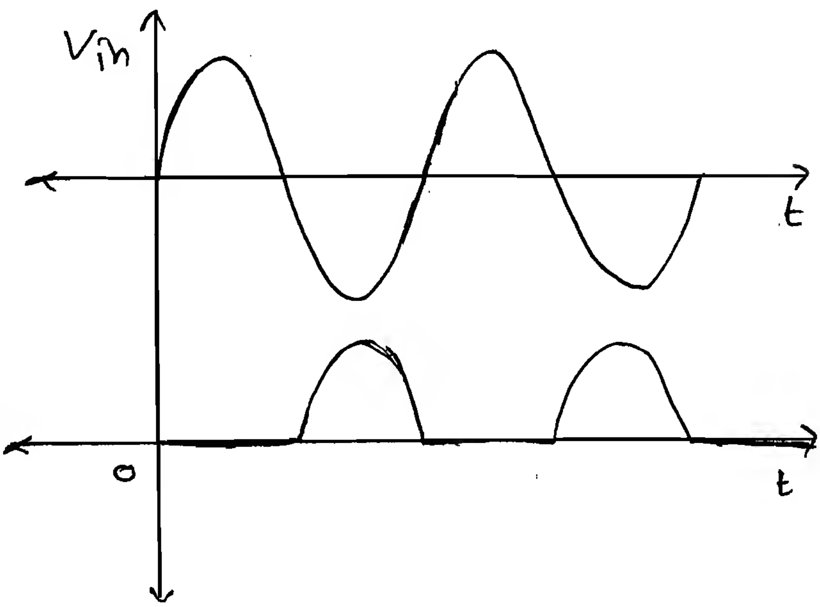


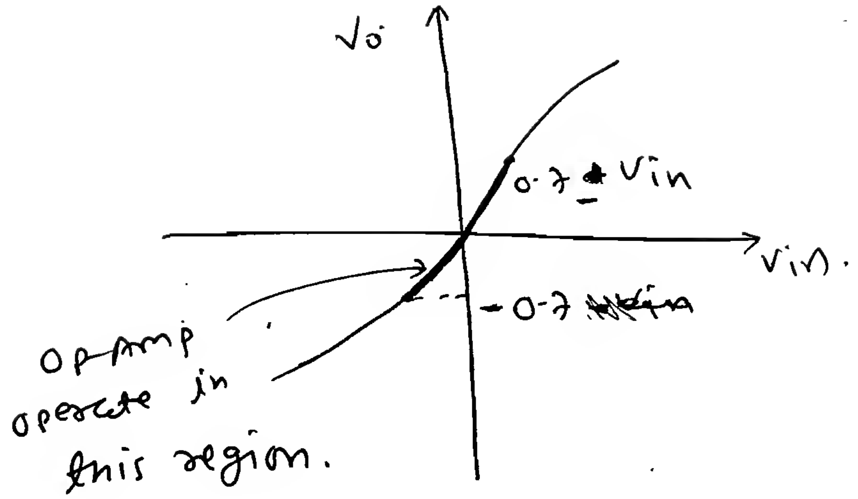
$$\frac{0 - V_{in}}{R} = \frac{0 - V_o}{R}$$

$\therefore \boxed{V_o = -V_{in}}$

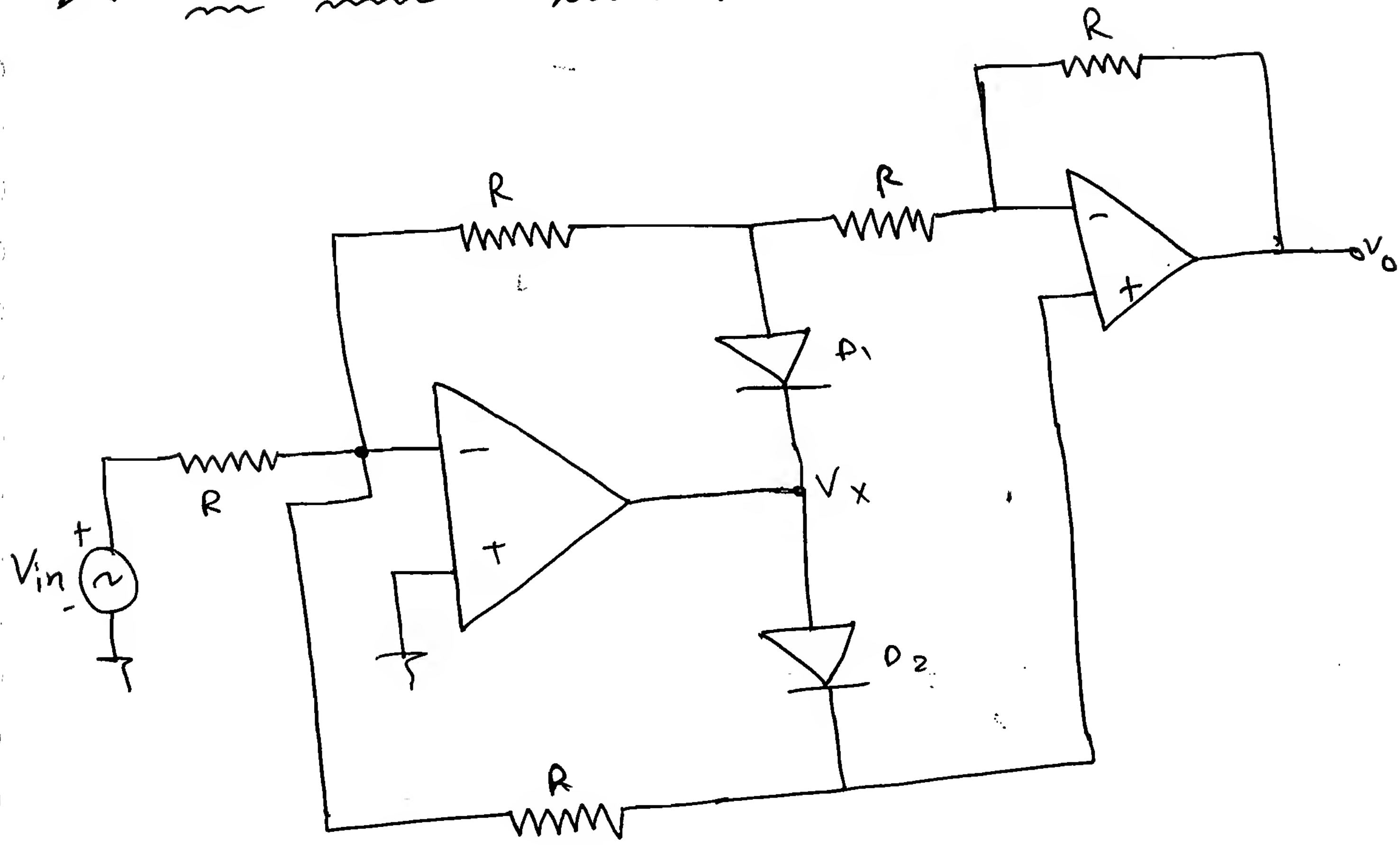
$\therefore V_x = 0.7 + V_o$

$\therefore \boxed{V_x = 0.7 \pm V_{in}}$



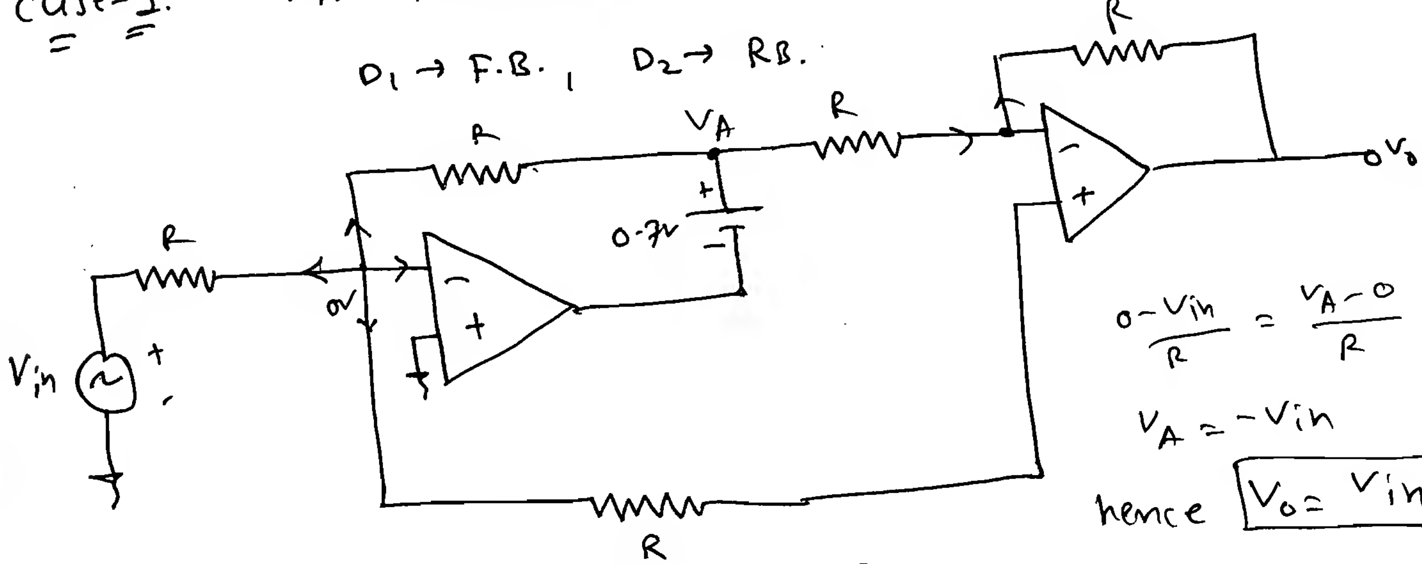


☆ Full Wave Rectifier:



case-I: Vin → positive ⇒ Vx ⇒ -ve

D_1 → F.B. , D_2 → RB.



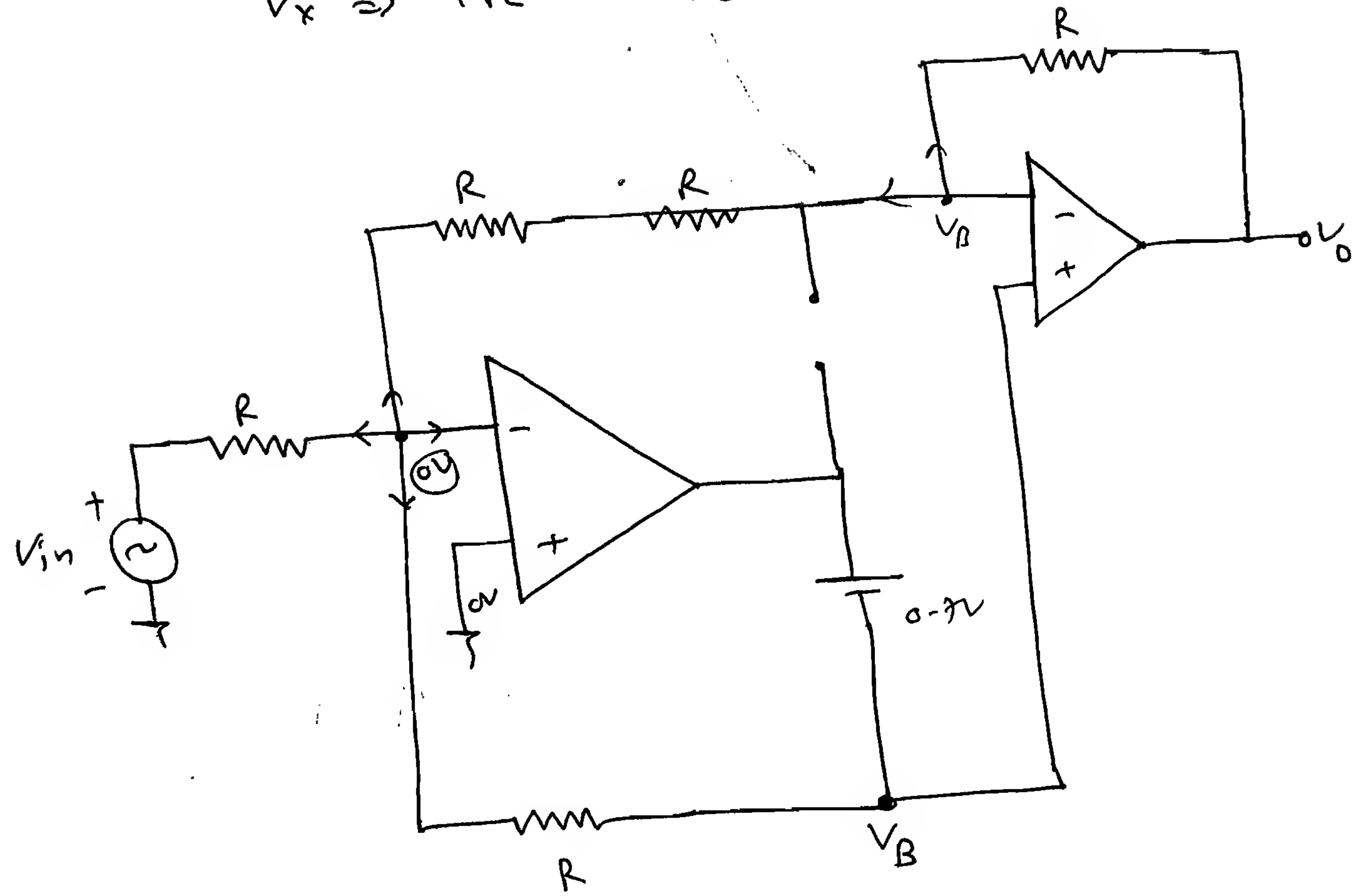
$$\frac{0 - V_{in}}{R} = \frac{V_A - 0}{R}$$

$$V_A = -V_{in}$$

hence $\boxed{V_o = V_{in}}$

case-2 : $V_{in} \Rightarrow -ve$ $D_1 = off$

$V_x \Rightarrow +ve$ $D_2 = ON.$



$$\rightarrow \quad \frac{0-V_{in}}{R} + \frac{0-V_B}{2R} + \frac{0-V_B}{R} = 0.$$

$$\therefore -2V_{in} - V_B - 2V_B = 0$$

$$\therefore V_B = -\frac{2}{3} \cdot V_{in}.$$

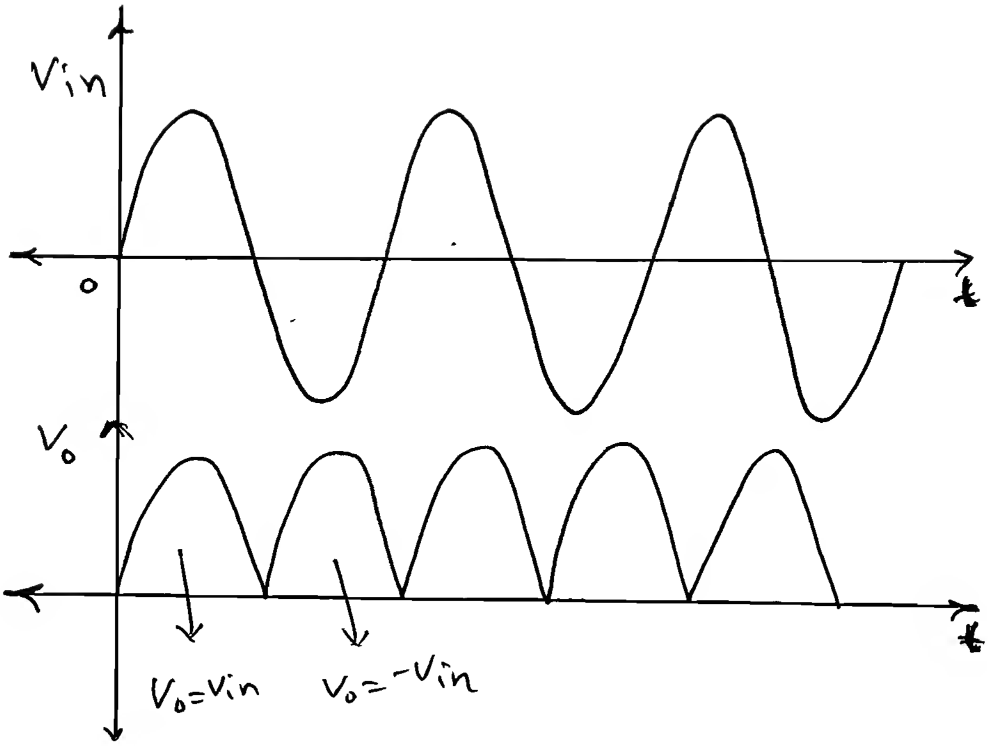
$$\rightarrow \quad \frac{V_B - 0}{2R} + \frac{V_B - V_o}{R} = 0.$$

$$\therefore \frac{V_B}{2R} + \frac{V_B}{R} - \frac{V_o}{R} = 0.$$

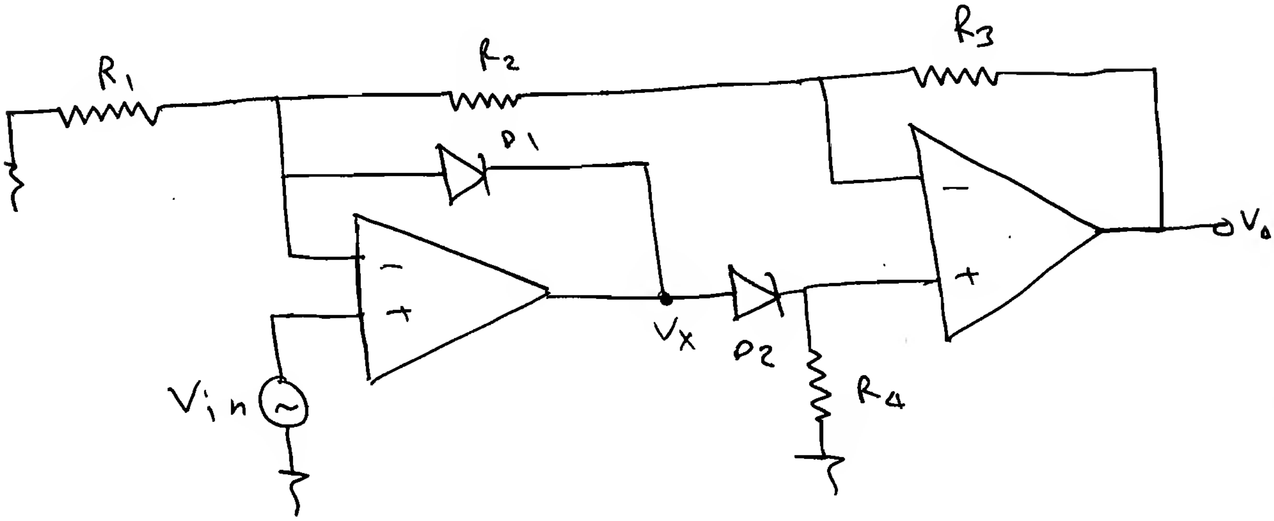
$$\therefore V_o = 3/2 \, V_B.$$

$$\therefore V_o = 3/2 \left(-2/3 \cdot V_{in}\right)$$

$$\therefore \boxed{V_o = -V_{in}}$$

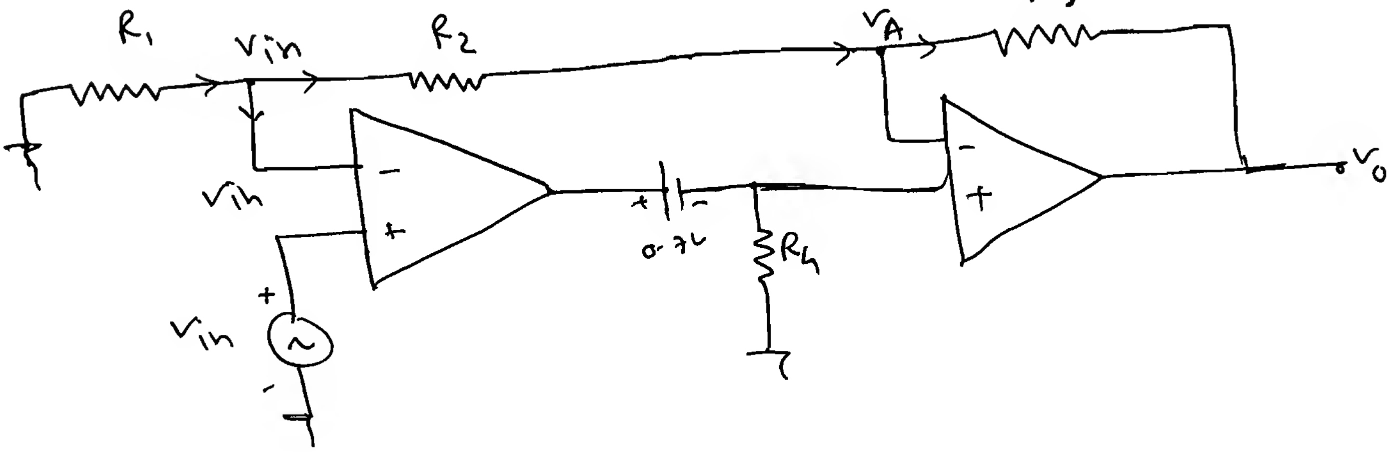


Ex-1: Find Vo if Vin=+ve & Vin=-ve.



Ans: (i) When Vin = +ve => Vx= +ve.

D2 is FB , D1 → RB.



$$\frac{0-V_{in}}{R_1} = \frac{V_{in}-V_a}{R_2}.$$

$$\frac{V_a}{R_2} = \frac{V_{in}}{R_2} + \frac{V_{in}}{R}. \qquad — ①$$

$$\therefore \frac{V_{in}-V_A}{R_2} = \frac{V_A-V_o}{R_3}.$$

$$\therefore \frac{V_{in}}{R_2} = \frac{V_A}{R_2} + \frac{V_A}{R_3} - \frac{V_o}{R_3}.$$

$$\therefore V_A\left[\frac{R_2+R_3}{R_2 \cdot R_3}\right] = \frac{V_{in}}{R_2} + \frac{V_o}{R_3}.$$

$$\therefore V_A = \left[\frac{V_{in}}{R_2} + \frac{V_o}{R_3}\right] \times \frac{R_2 \cdot R_3}{R_2+R_3} \qquad — ②$$

$\therefore$ Put ② in ①

$$\frac{R_3}{R_2+R_3}\left[\frac{V_{in}}{R_2} + \frac{V_o}{R_3}\right] = V_{in}\left[\frac{R_1+R_2}{R_2 \cdot R_1}\right].$$

$$\therefore \frac{R_3}{R_2(R_2+R_3)}V_{in} + \frac{V_o}{R_2+R_3} = V_{in}\left[\frac{R_1+R_2}{R_2 \cdot R_1}\right].$$

$$\therefore \frac{0-V_{in}}{R_1} = \frac{V_{in}-V_o}{R_2+R_3}.$$

$$\therefore \frac{-V_{in}(R_2+R_3)}{R_1} = R_1(V_{in}) - RV_o.$$

$$\therefore R_1V_o = V_{in}(R_1+R_2+R_3).$$

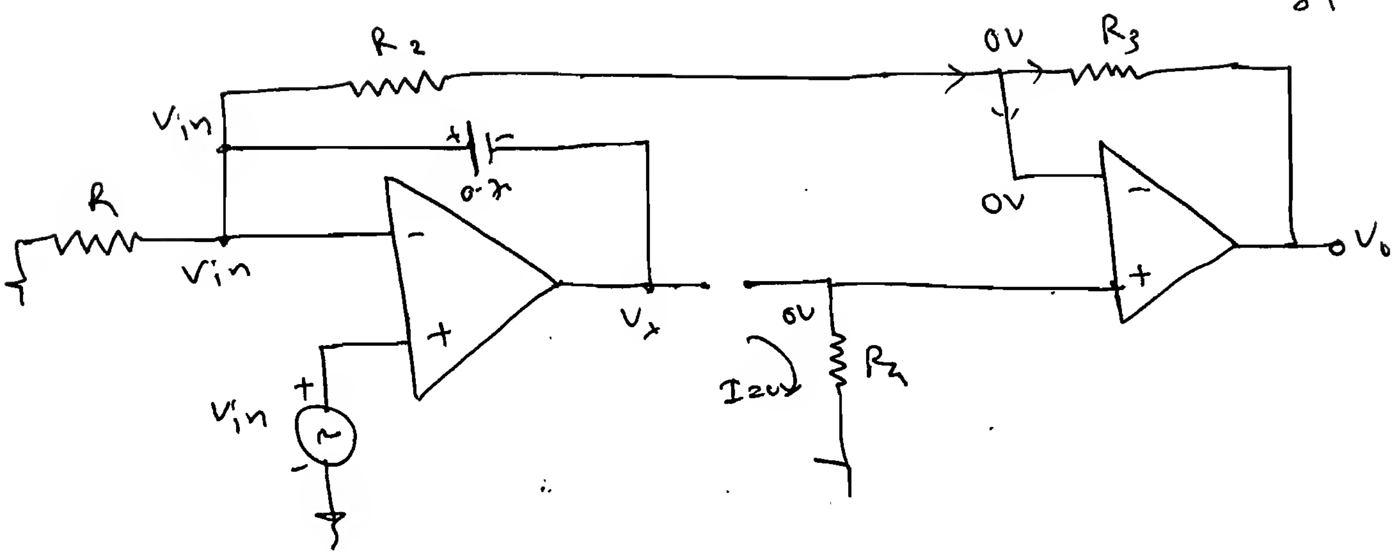
$$\therefore \boxed{V_o = \frac{R_1+R_2+R_3}{R_1} V_{in}}$$

② when $V_{in} = -ve.$

$V_x \Rightarrow +Ve.$

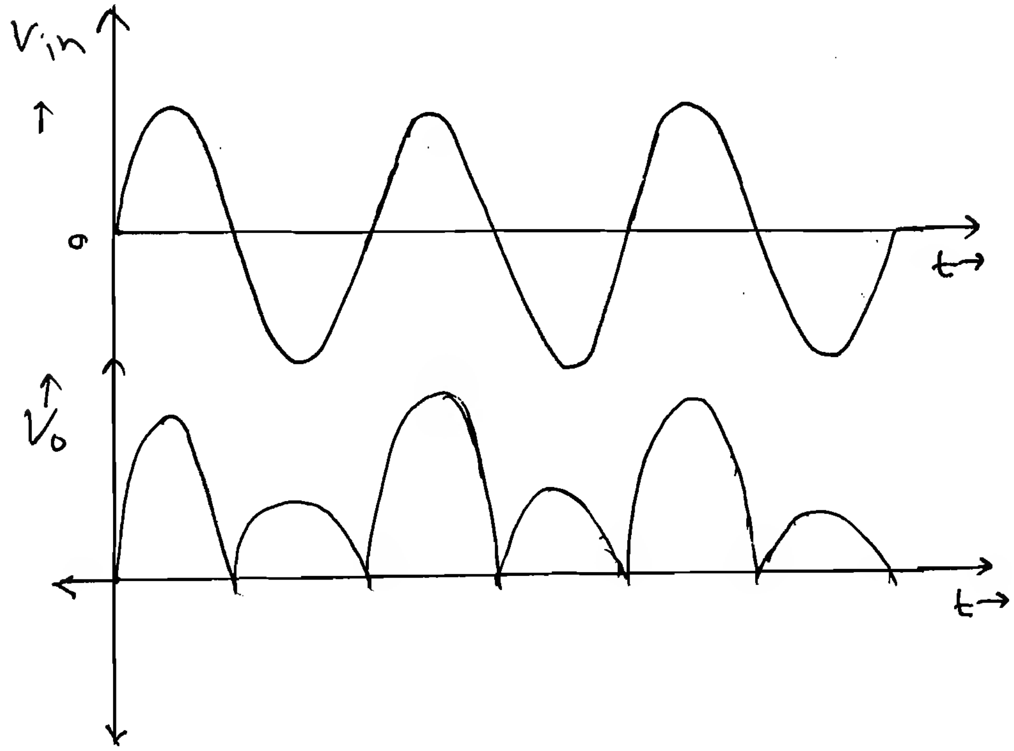
$D_2 \rightarrow R.B.$

$D_1 \rightarrow F.B.$

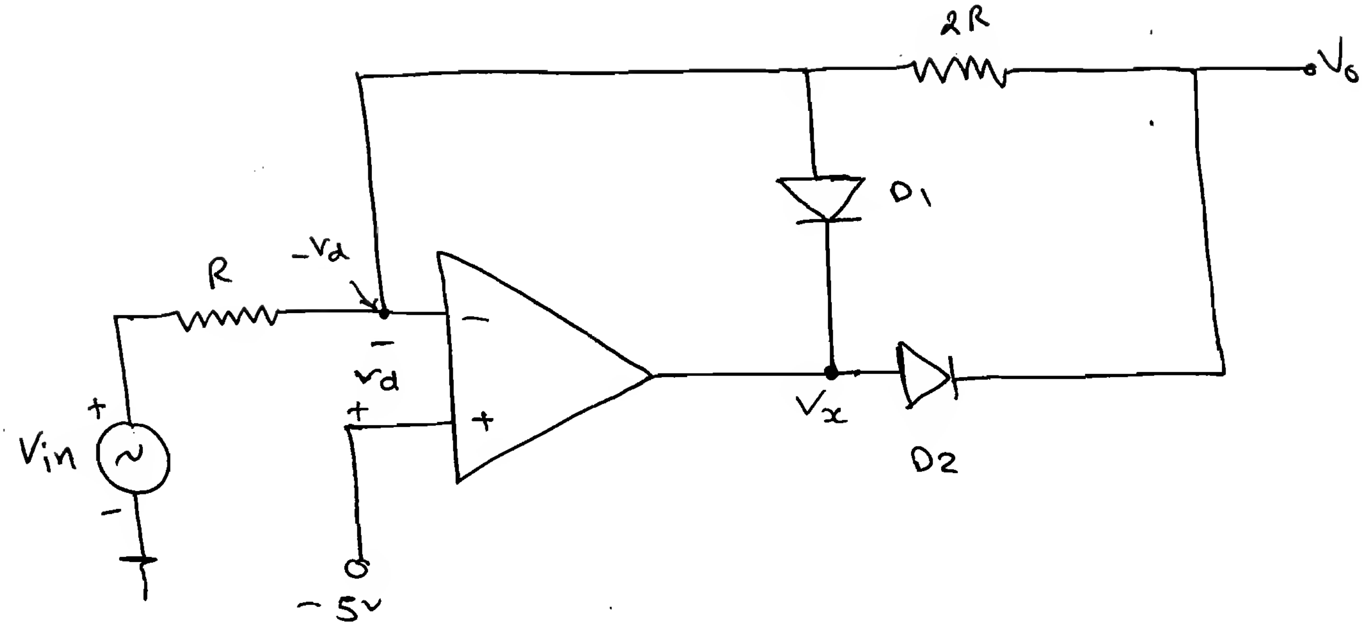


$$\therefore \quad \frac{V_{in}-0}{R_2} = \frac{0-V_0}{R_3}.$$

$$\therefore \quad \boxed{\frac{V_0}{V_{in}} = -\left(\frac{R_3}{R_2}\right)} \quad \Rightarrow \quad V_0 = -\left(\frac{R_3}{R_2}\right)V_{in}.$$



Ex-2

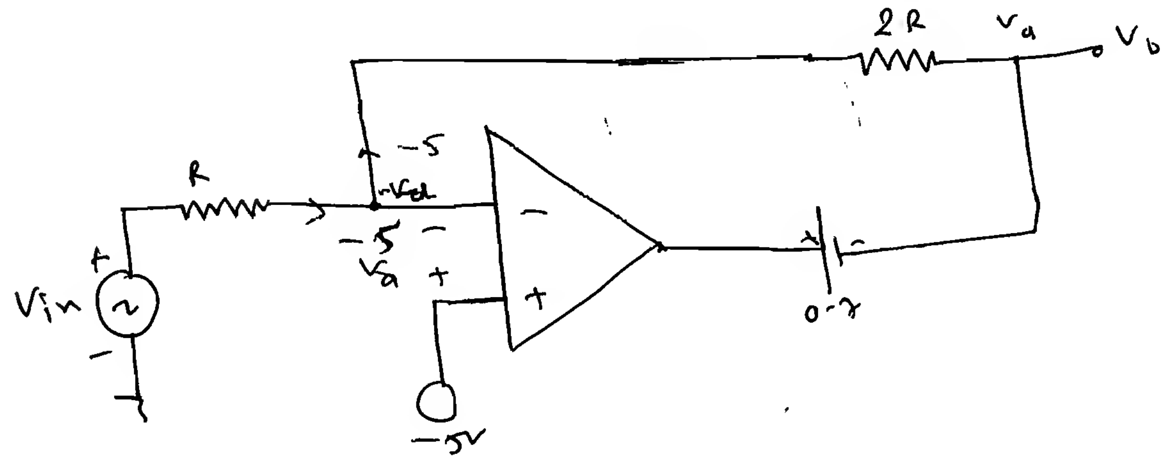


Ans: Case-(ii) $V_d > 0$, $V_d = -V_{in} - 5 > 0$

$V_{in} < -5$ V.

$V_d > 0 \Rightarrow V_x = +ve$.

∴ $D_1 \to$ R.B. , $D_2 \to$ F.B.



$$\therefore \frac{V_{in} - (-V_d)}{R} = \frac{-V_d - V_o}{2R}. \qquad V_d = 5.$$

$\therefore 2V_{in} + 2V_d = -V_d - V_o$

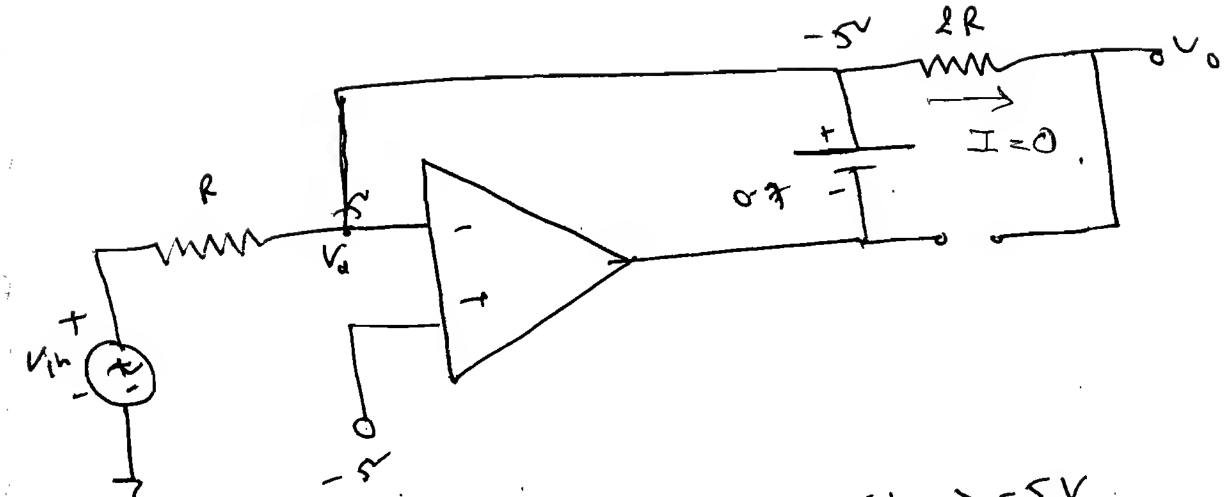
$3V_d = -V_o - 2V_{in}$.

$15 = -V_o - 2V_{in}$.

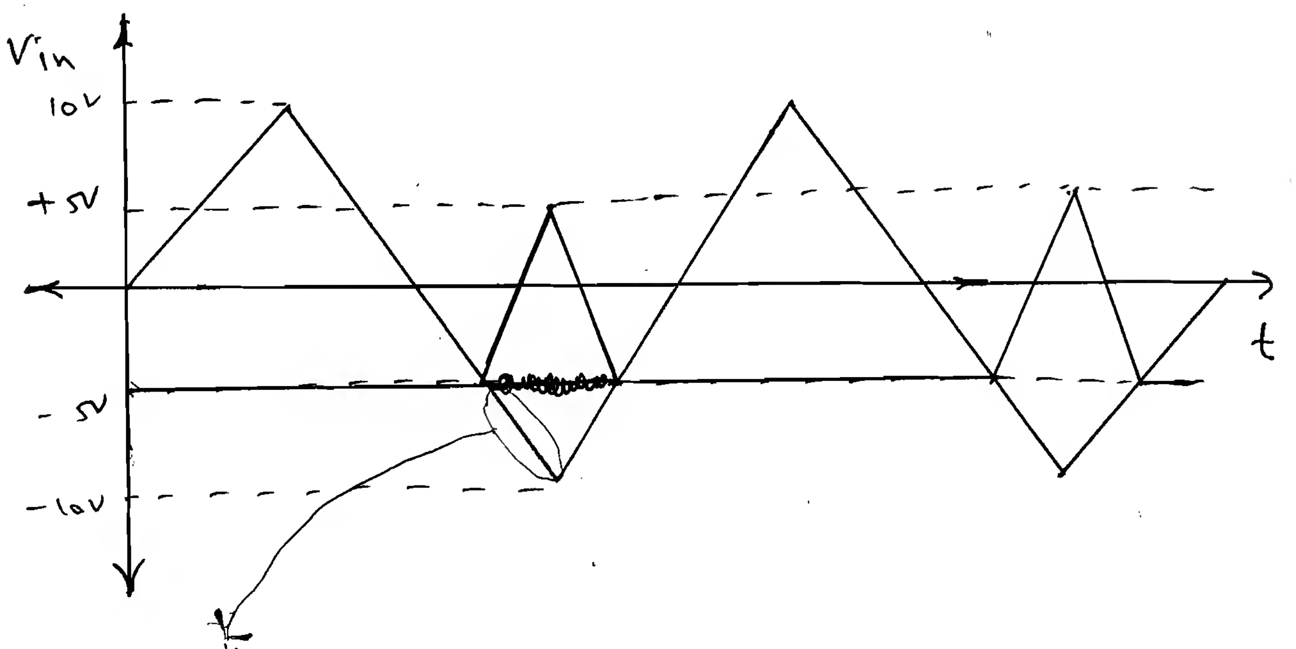
$\therefore \boxed{V_o = -(15 + 2V_{in})}$ for $V_{in} < -5$.

(2) $V_{in} > -5 \Rightarrow$ D_1 = R.B. $V_x = -ve$

∴ $V_d < 0$ D_2 = R.B.



So, $\underline{V_o = -5V \quad \text{for} \quad v_{in} > -5V}$

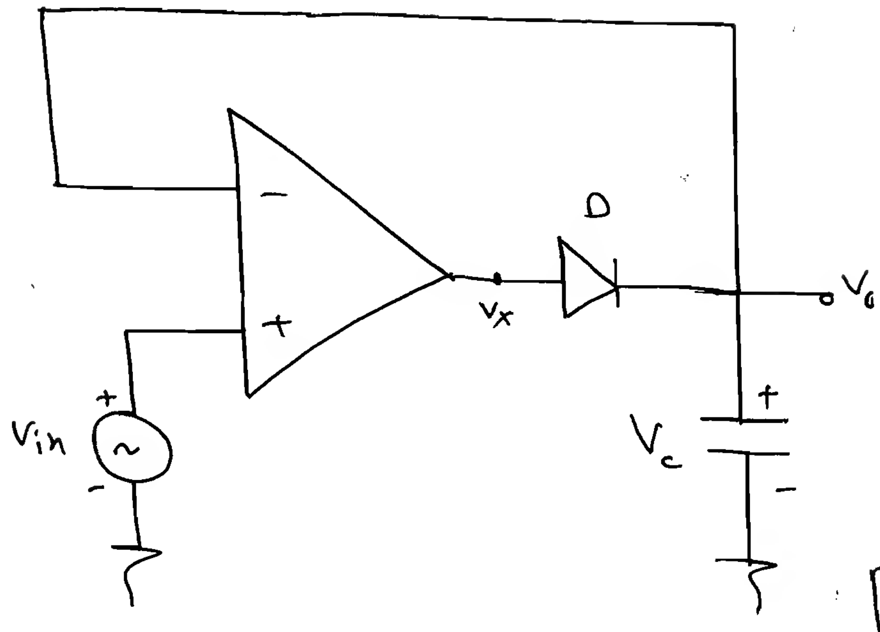


$v_{in} < -5 \Rightarrow$

V_{in}	$v_o = -(2V_{in}+15)$
-5	-5
-6	-3
-7	-1
-8	+1
-9	+3
-10	+5

* Peak Detector:

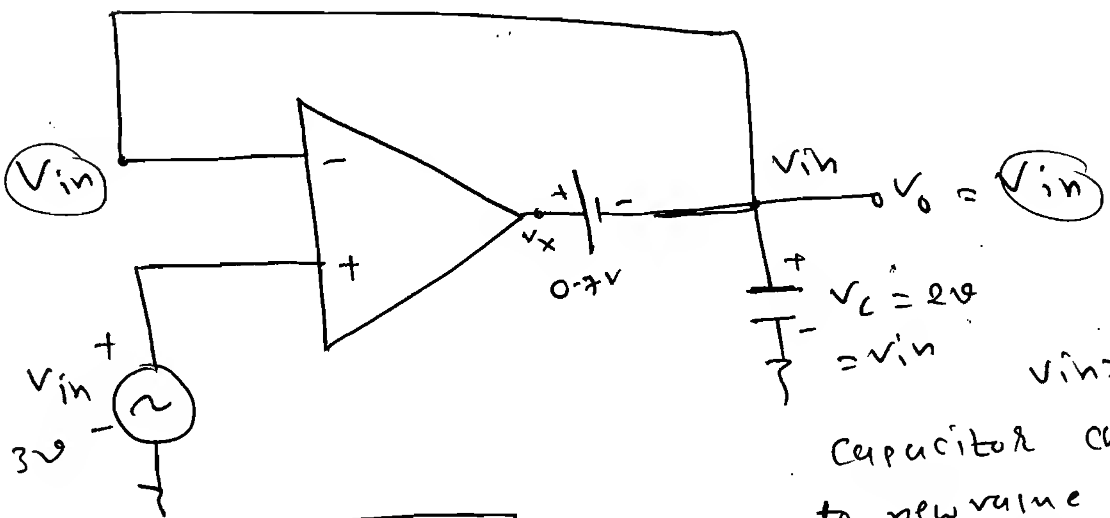
⇒



$\boxed{V_x = V_{in} + V_c}$

⇒ Case (1): when $V_{in} > V_c$. V_x is +ve.

D → F.B.



$V_{in} > V_c$

capacitor charges to new value $V_{in} > V_c$ i.e. 3V.

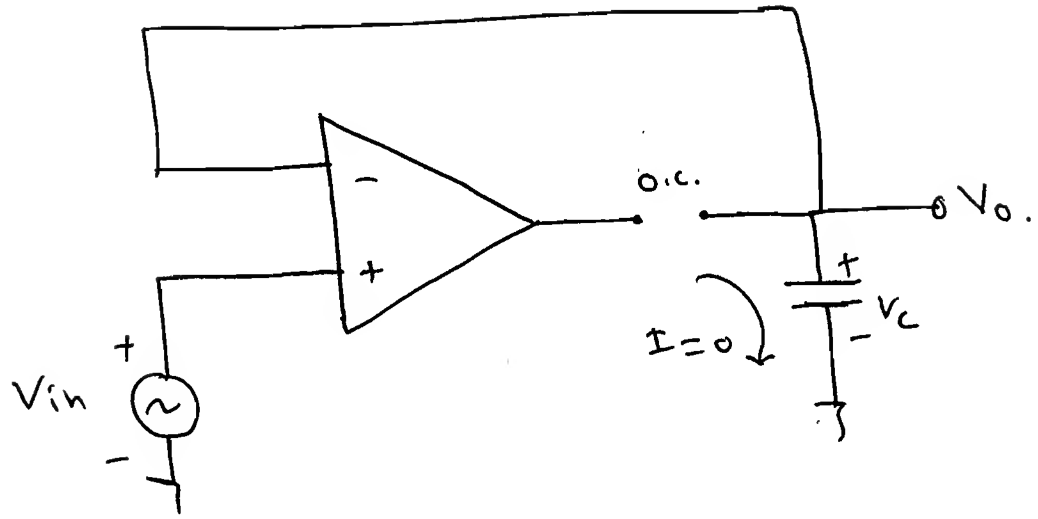
$\boxed{V_o = V_{in}}$

∴

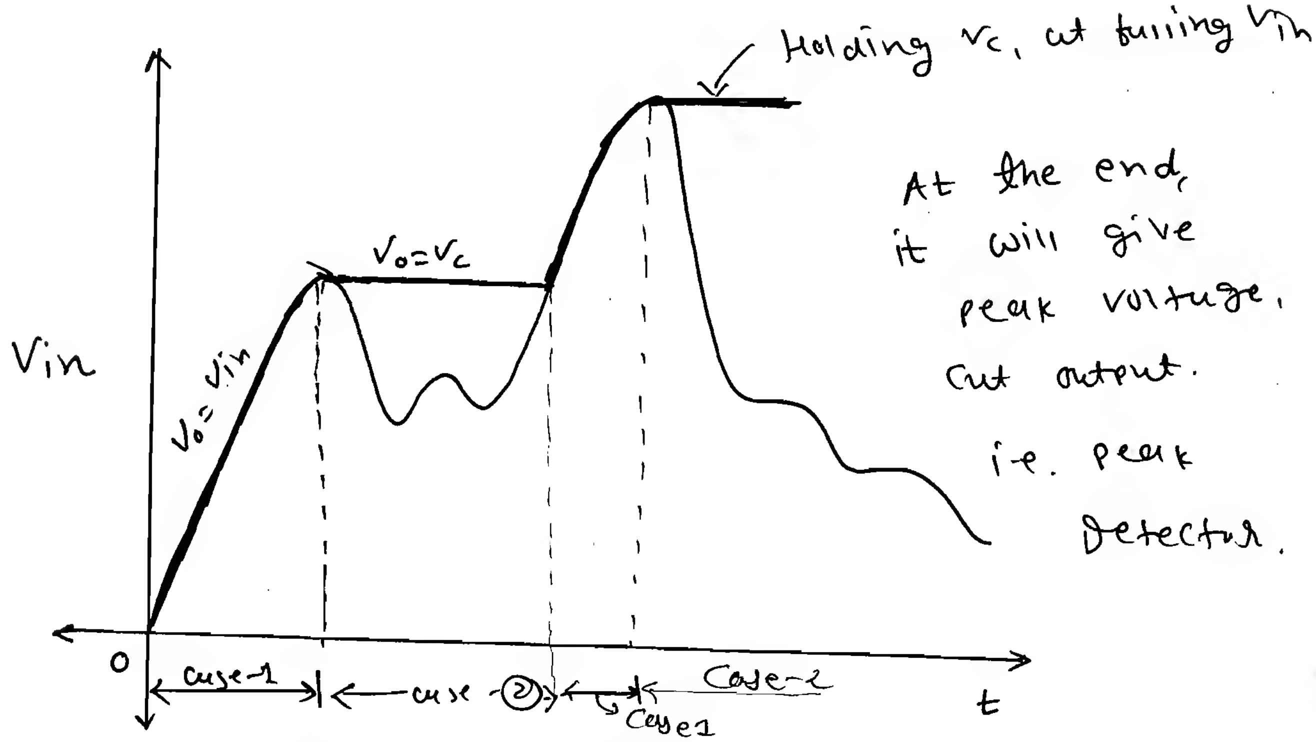
case-2: when $V_{in} < V_c$.

∴ D → R.B. (∵ V_x = −ve).

diode → R.B.

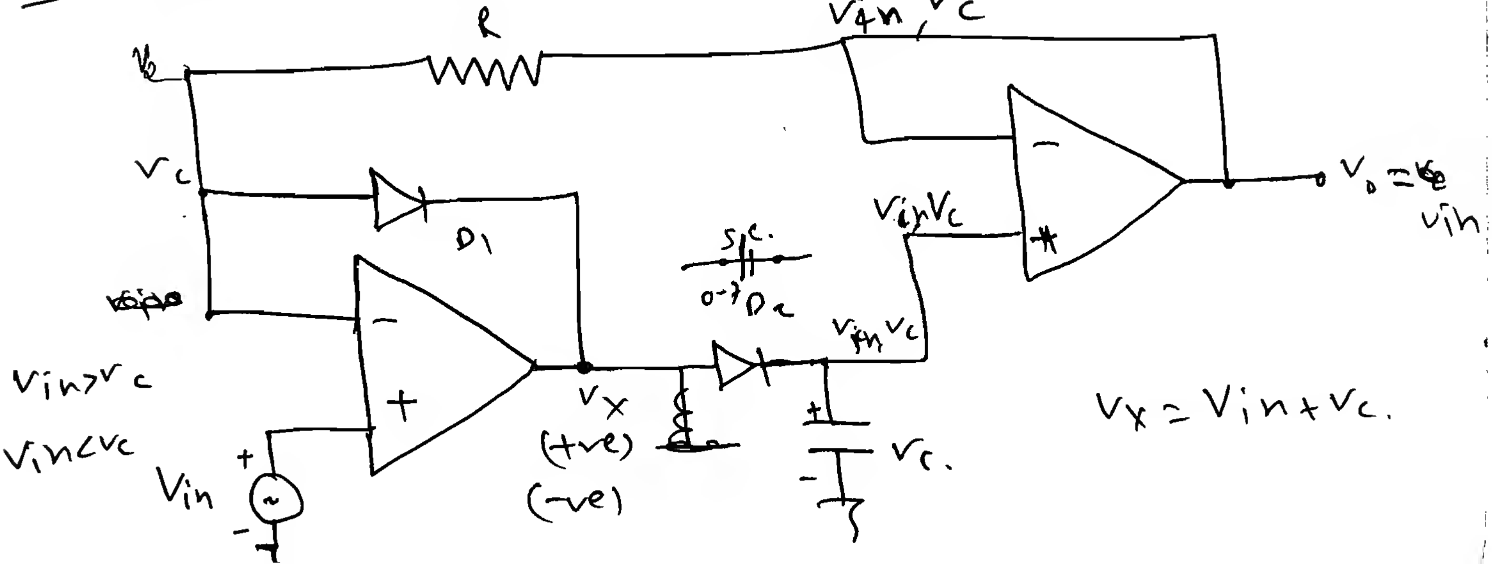


so, $\boxed{V_o = V_c}$ until next $V_{in} > V_c$.



At the end, it will give peak voltage, at output. i.e. peak Detector.

* Improved peak Detector:

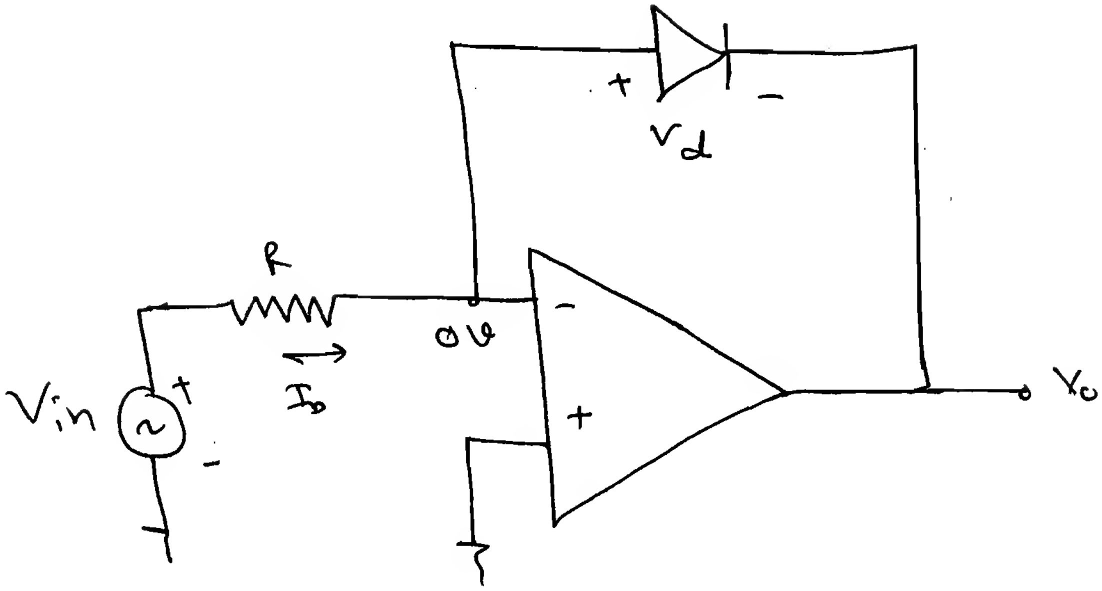


$V_x = V_{in} + V_c$.

☆ Log Amplifier:

$$I_d = I_s e^{V_d/V_t}$$

$$V_d = V_t \ln\left(\frac{I_D}{I_s}\right)$$



$$\therefore I_D = \frac{V_{in} - 0}{R}$$

$$I_D = \frac{V_{in}}{R}.$$

$$\therefore 0 - V_o = V_d.$$

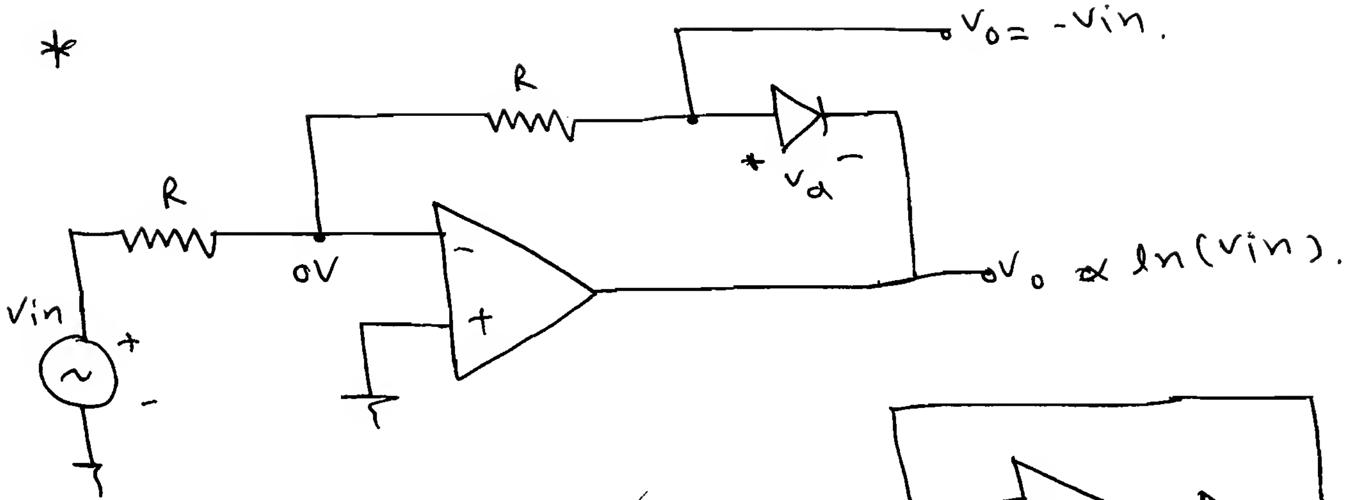
$$\therefore \boxed{V_D = -V_o}$$

Now, $$V_d = V_t \ln\left(\frac{I_D}{I_s}\right)$$

$$\therefore V_o = -V_t \ln\left[\frac{V_{in}}{R I_s}\right].$$

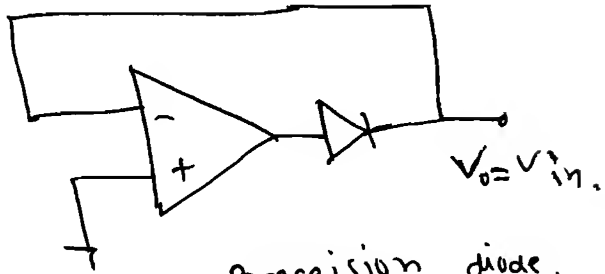
$$\therefore \boxed{V_o \propto \ln(V_{in}).}$$

*



$$\frac{0 - V_{in}}{R} + \frac{0 - V_o}{R_1} = 0.$$

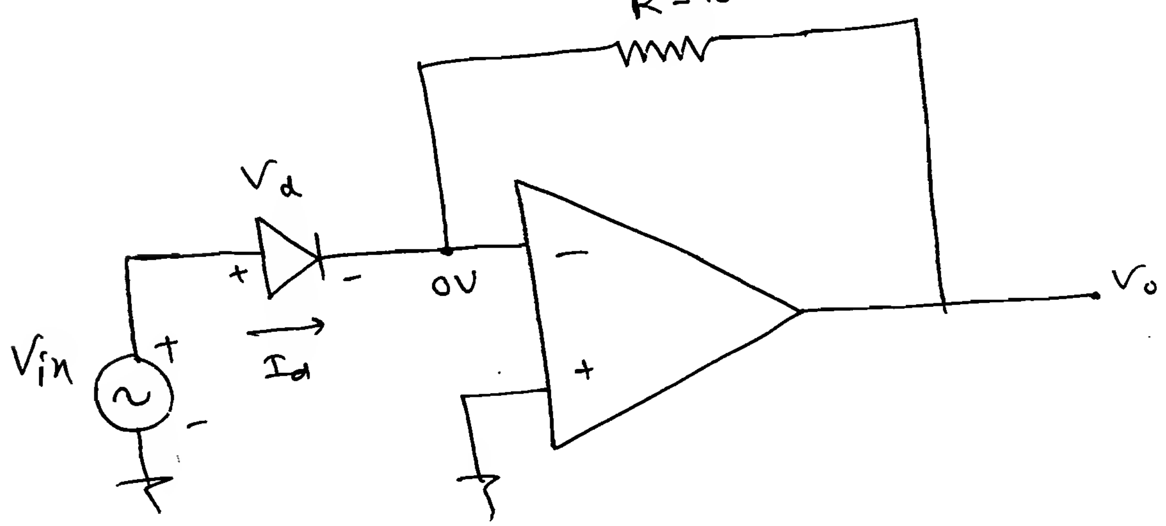
$$\therefore \boxed{V_o = -V_{in}}$$



Preceision diode.

→ If we involve V_d in o/p then it is log operation otherwise precesion diode.

Exponetical Amplifier:



$$\therefore I_D = \frac{0 - V_o}{R}.$$

$$\therefore V_o = -R I_D$$

$$\therefore V_o = -R I_s e^{V_D/V_t}.$$

$$\therefore V_o = -R I_s e^{V_{in}/V_t}$$

But $V_d = V_{in}$

$$\boxed{V_o \propto e^{V_{in}}}$$

Now $\eta = 1$, $V_t = 25mV$, $I_s = 10^{-13}$ A., $V_{in} = 0.68$

$$\therefore \quad V_o = -100 \times 10^{-13} \left[e^{\frac{0.68}{25\times10^{-3}}} \right].$$

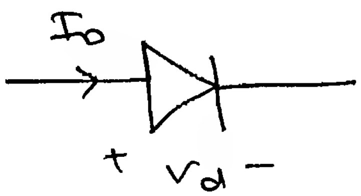
$$\therefore \quad \boxed{V_o = -6.5\ V}$$

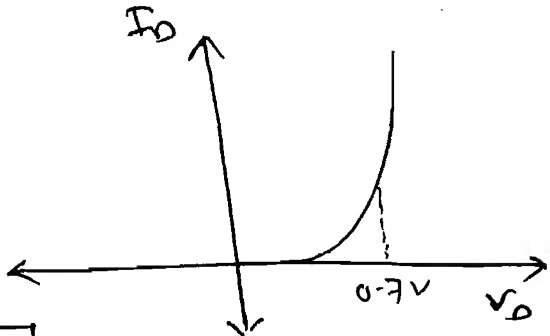
☆ Small Signal Analysis :-

→ Amp is linear operation.

→ Nonlinear devices are as follow:

(1) Diode:

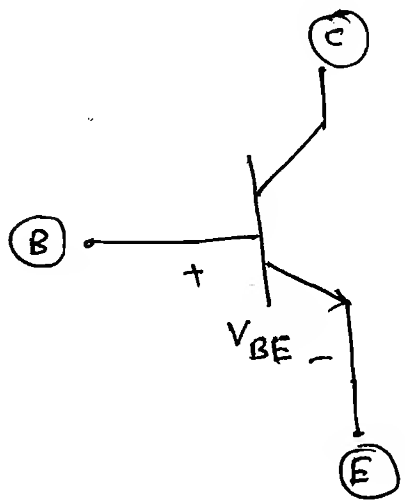


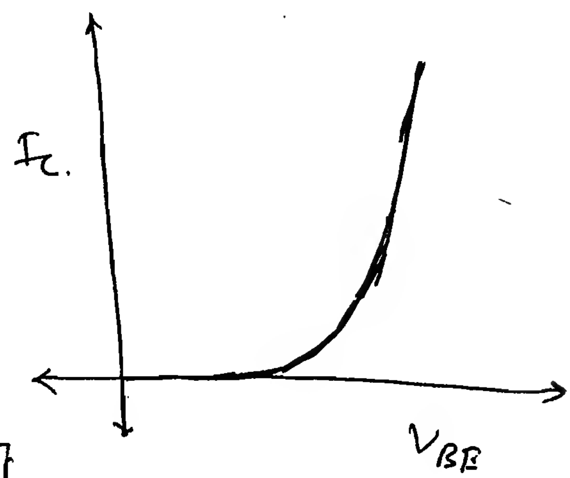


$$\boxed{I_D = I_s \cdot e^{V_d/V_t}}$$

(2)

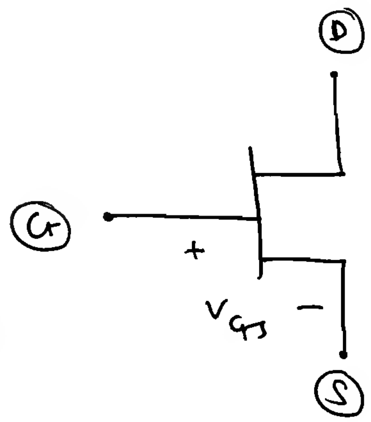
BJT:

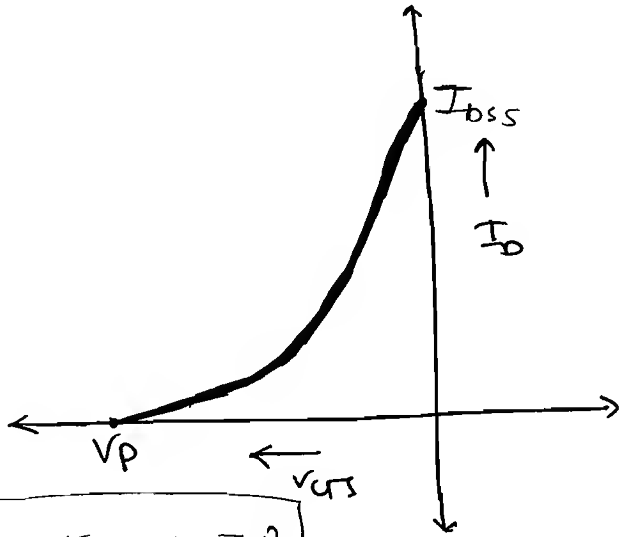




$$\boxed{I_C = I_s \cdot e^{V_{be}/V_t}}$$

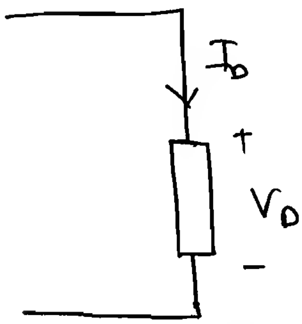
③ FET:



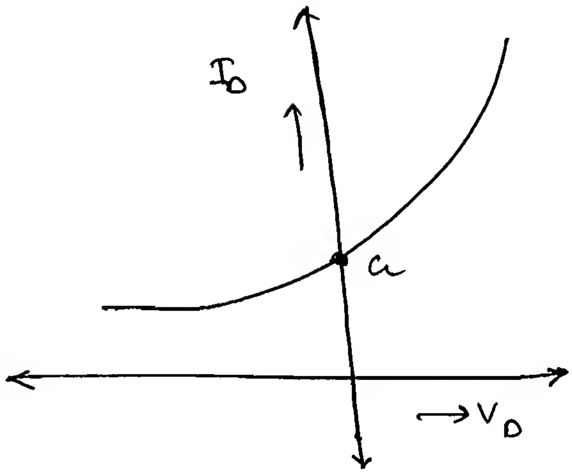


$$\boxed{I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_P}\right]^2}$$

*



$$\boxed{I_D = a e^{bV_D}}$$

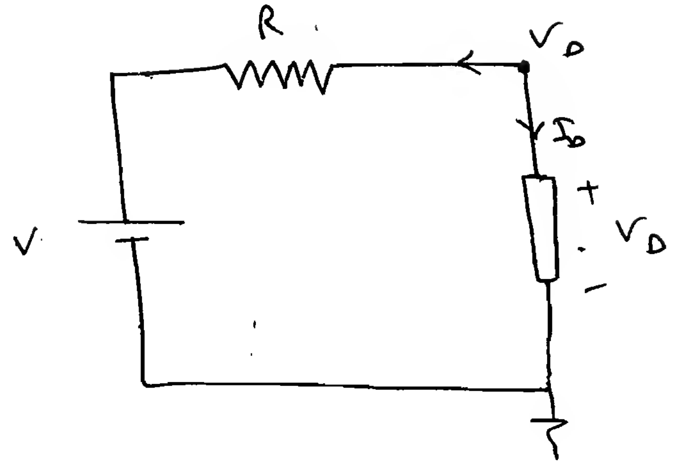


*

KVL, KCL

linear	Non-linear
Thevinian	
Norton	
Superposition	

* Dc Analysis:



KCL, $\dfrac{V_D - V}{R} + I_D = 0$ —(1)

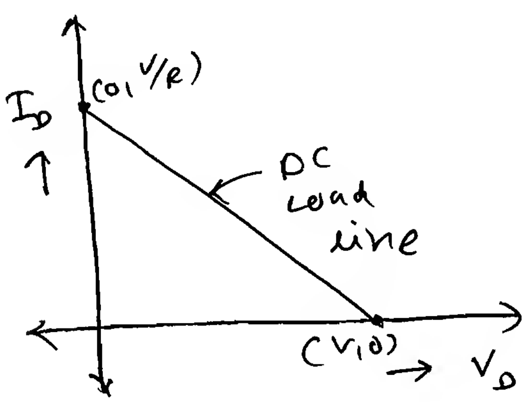
Now, $I_D = \cancel{I_S/R}\ a e^{bV_D}$

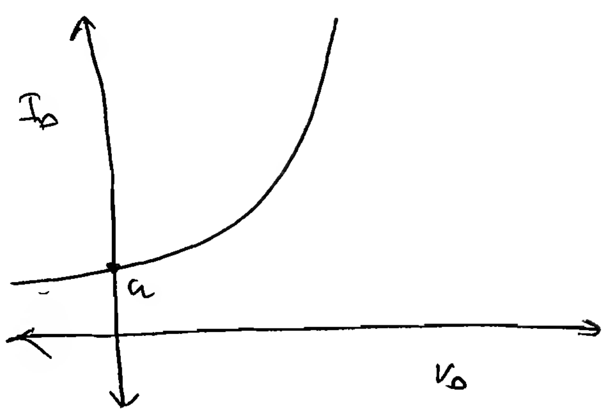
$$\therefore \boxed{\frac{V_D - V}{R} + a e^{bV_D} = 0}$$

Solve By (1) trial and error.

(2) Iteration [Numerical method].

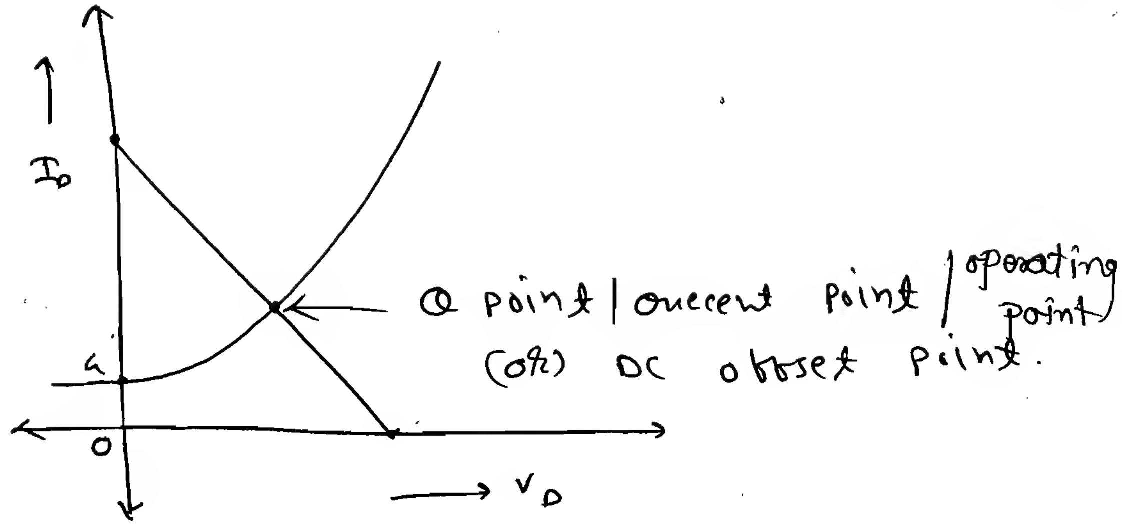
* graphical:



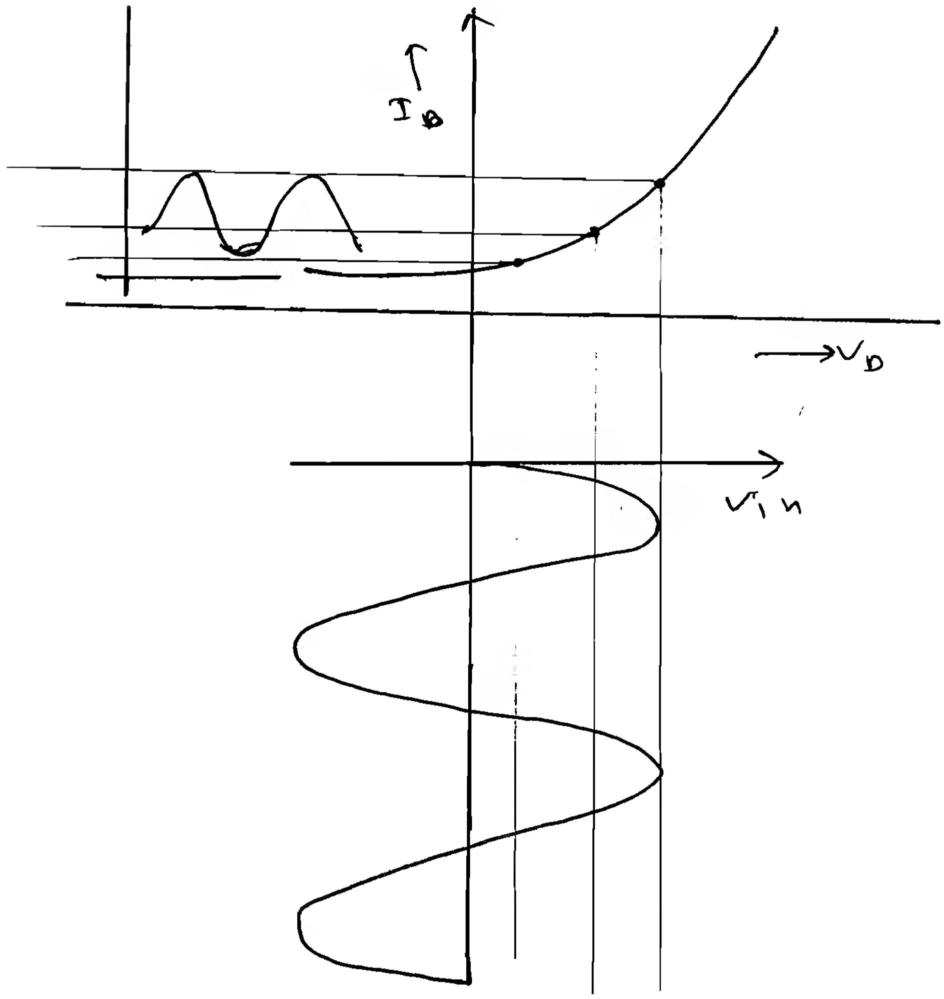


V_D	I_D
V ($\cancel{0}$)	0
0	V/R

*

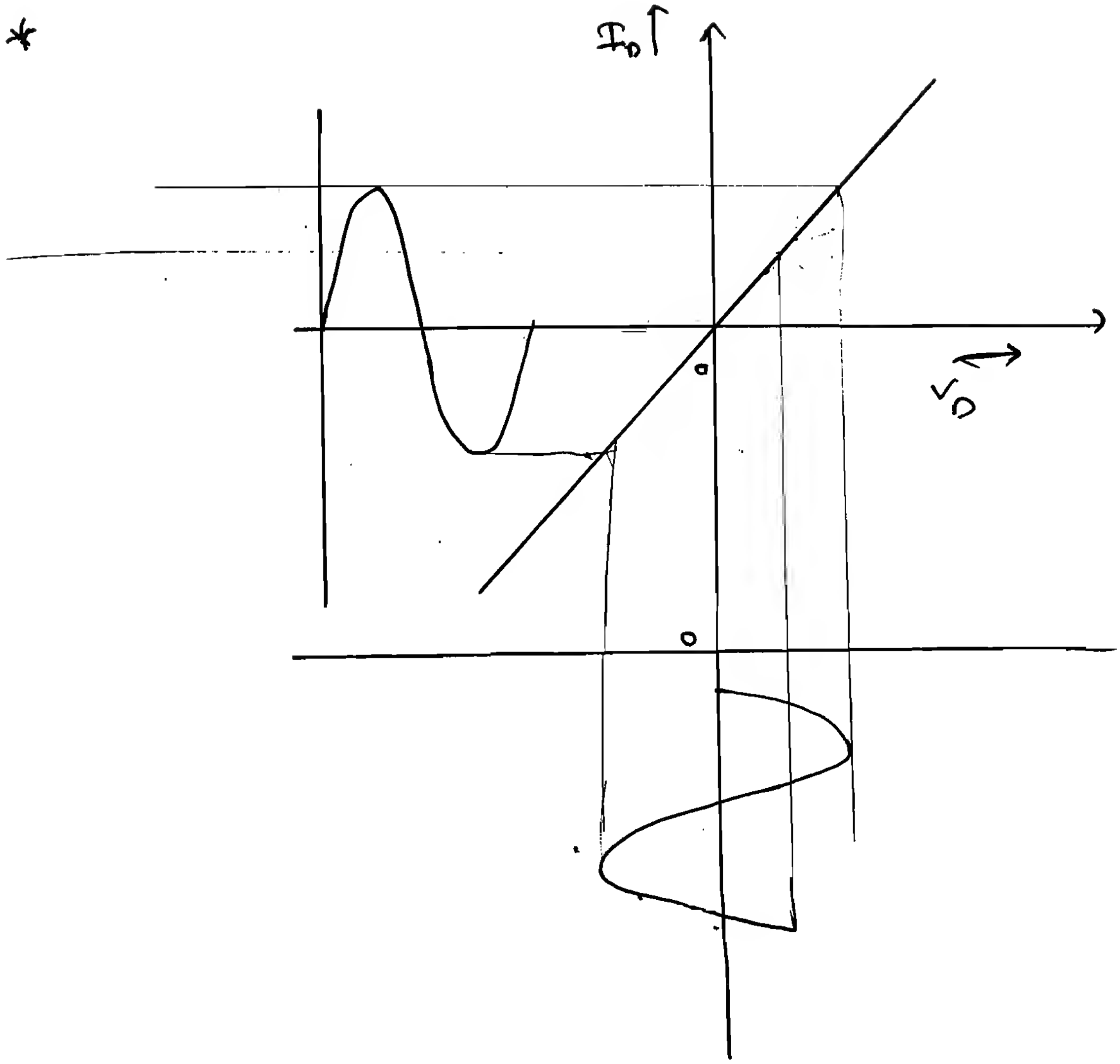


*

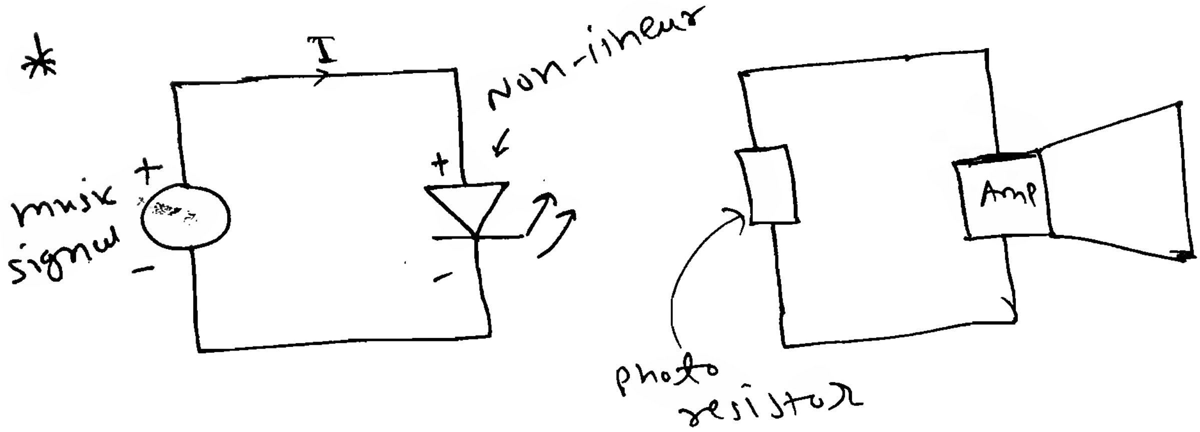


→ In order to get same shape at output, the characteristic must be linear. So, BJT, and ~~has~~ all active device has non-linear device and they do not gave same shape as input is very large. So some solⁿ is required.

*



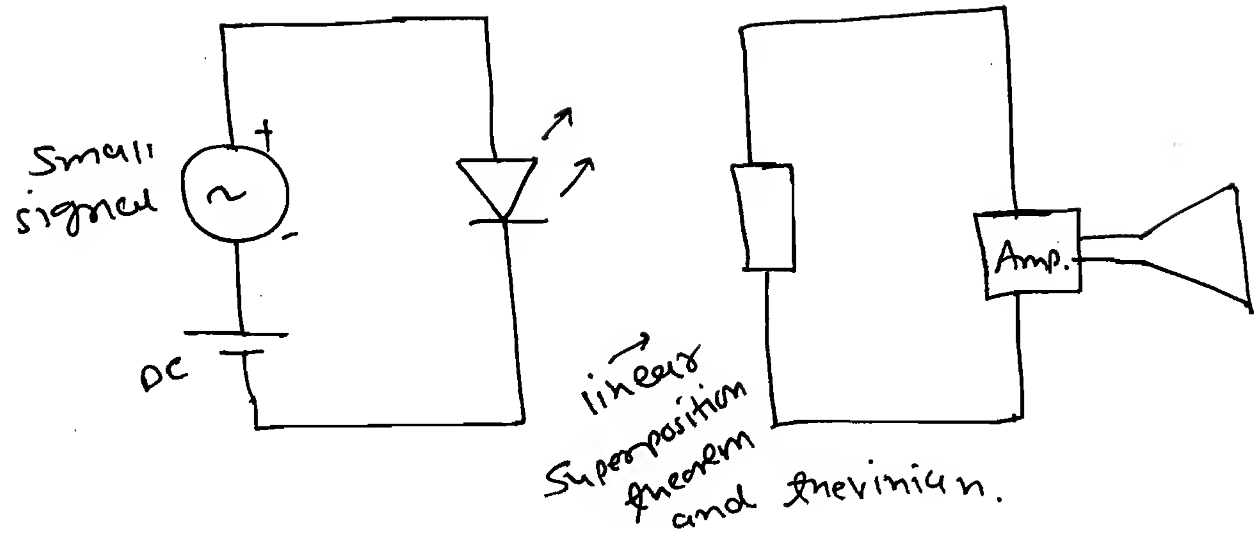
*



→ In order to get same shape of input at output (Amplified), Amp should follows the same shape of photo resistor and in order to do this photo resistor should follow shape available at LED and LED should follow input shape

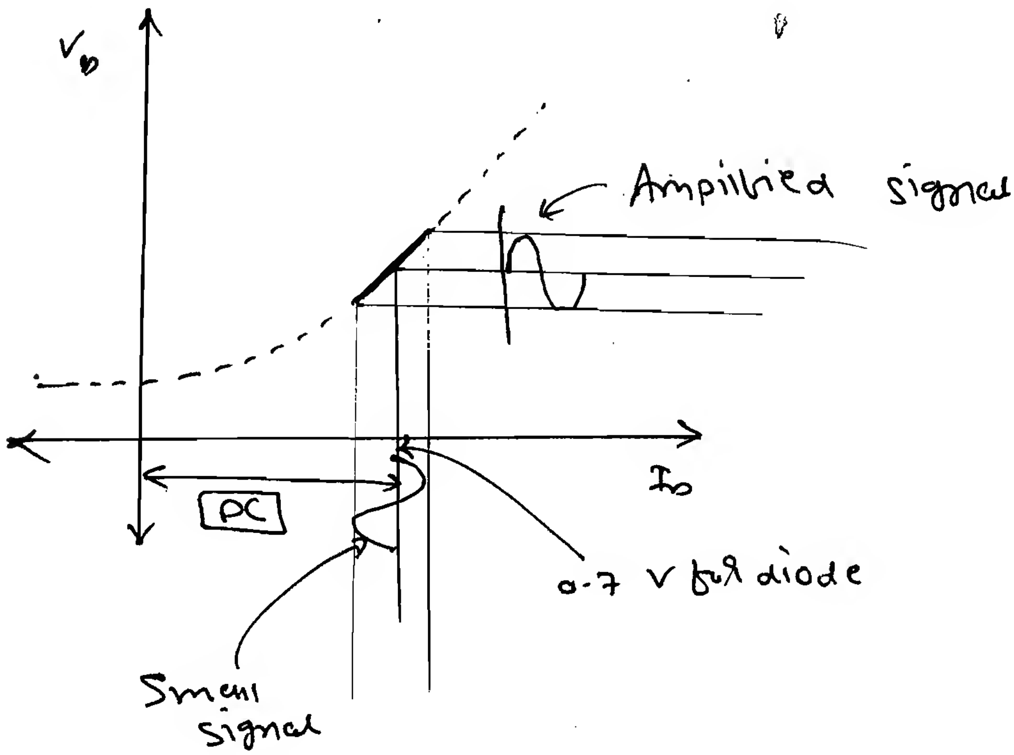
→ so, this is the linear operation then O/P is same as the input.

Correction:



adding dc = biasing.

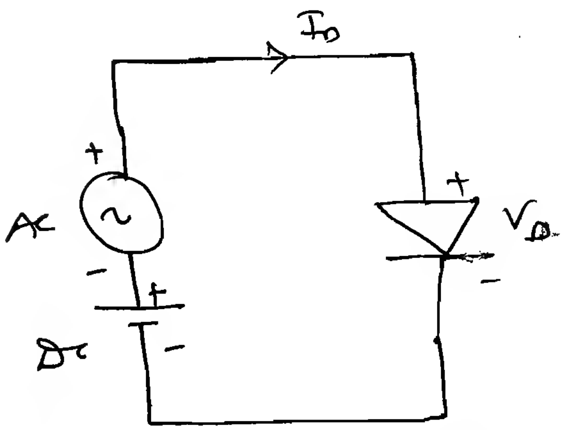
→ Now, All devices has same shape of voltage which is at input.



☆ Small Signal Analysis :

1) Add DC
2) keep the signal small.
3) non linear ⇒ linear.

* Small signal Analysis of Diode:



$$V_{D\,total} = V_{D_{DC}} + V_{D_{AC}}.$$

$$I_{D\,total} = I_{D_{DC}} + I_{D_{AC}}.$$

$$\rightarrow \quad I_D = I_s e^{V_D/V_t}.$$

$$I_{D.DC} = I_s \cdot e^{V_{DDC}/V_t} \quad \text{—} \ ①$$

$$I_{D\,total} = I_s e^{\frac{V_{D\,total}}{V_t}}$$

$$= I_s \cdot e^{\frac{V_{DDC} + V_{DAC}}{V_t}}$$

$$\therefore I_{D\,total} = I_s \cdot e^{\frac{V_{DDC}}{V_t}} \cdot e^{\frac{V_{DAC}}{V_t}} = I_{D_{DC}} \cdot e^{\frac{V_{DAC}}{V_t}}$$

$$\Downarrow$$

$$e^{\frac{V_{DAC}}{V_t}} = \left[1 + \frac{V_{D_{AC}}}{V_t}\right]$$

$$\therefore I_{D\,total} = I_{D.DC}\left[1 + \frac{V_{DAC}}{V_t}\right] \Longleftarrow$$

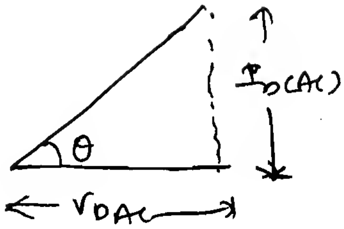
$$\therefore \cancel{I_{D}}_{DC} + I_{DAC} = \cancel{I_{D}}_{DC} + I_{D.DC} \cdot \frac{V_{DAC}}{V_t}$$

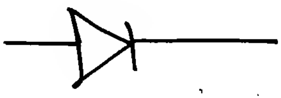
$$I_{D_{AC}} = I_{D_{DC}} \cdot \frac{V_{D_{AC}}}{V_t}.$$

→ Diode Resistance,

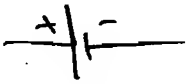
$$(r_d) = \frac{V_{D_{AC}}}{I_{D_{AC}}} = \frac{V_t}{I_{D_{DC}}} = \text{const.}$$

$$\therefore \; r_d = \frac{V_t}{I_D}.$$





$\boxed{DC}$



0.7 V

AC

$$r_d = \frac{V_t}{I_{D_{DC}}}$$

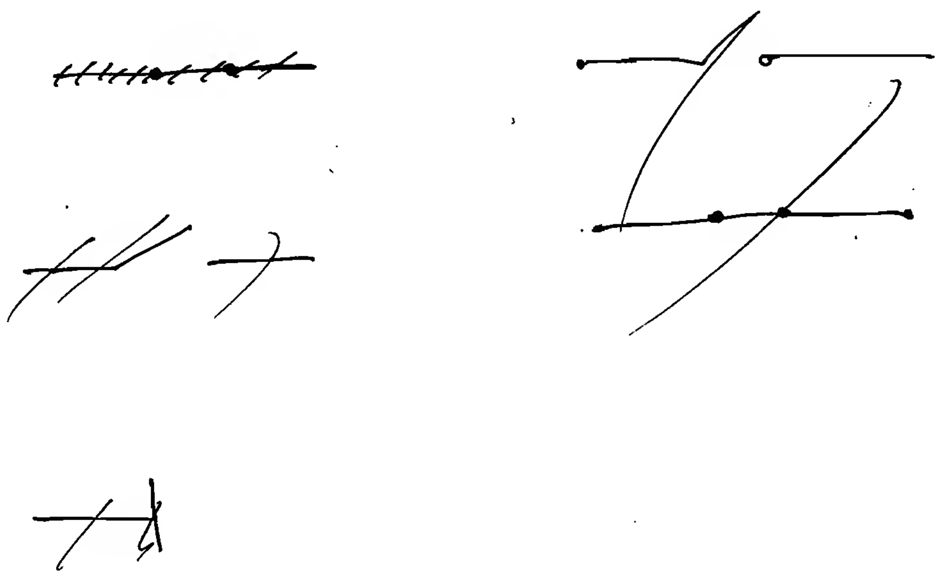
Diode work as a linear Device.

~~DC ($\omega = 0$)~~ ~~AC (ω = high).~~

1. Resistor
R Ω

2. Inductor
$|\omega L|$

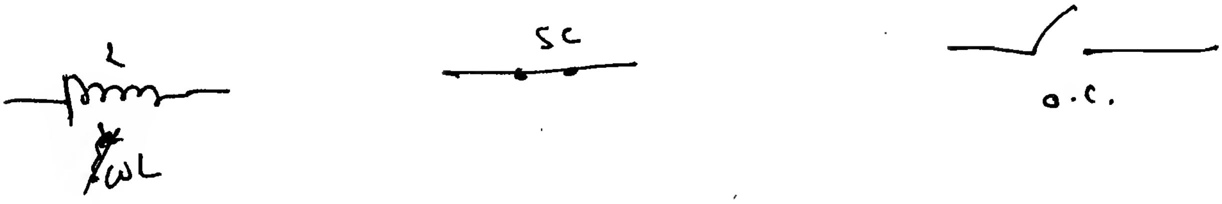
3. Capacitor
C
$\frac{1}{\omega C}$



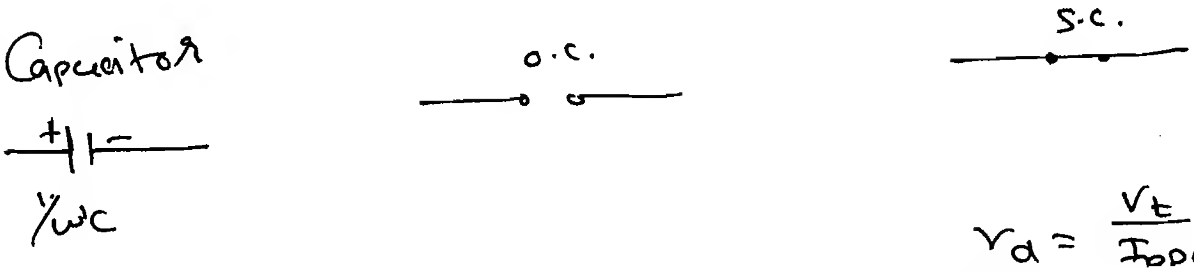
	DC ($\omega = 0$)	AC (ω = high).

1. Resistor

2. Inductor

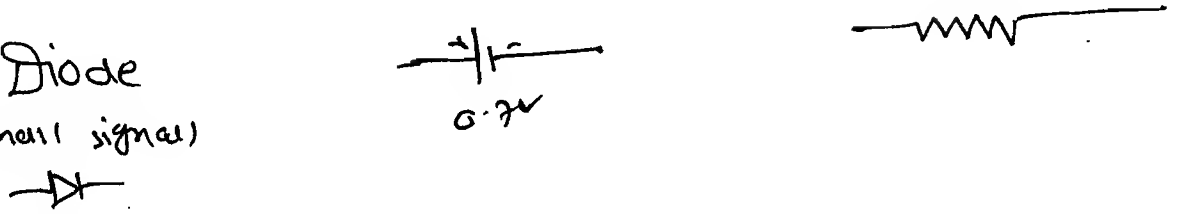


3. Capacitor

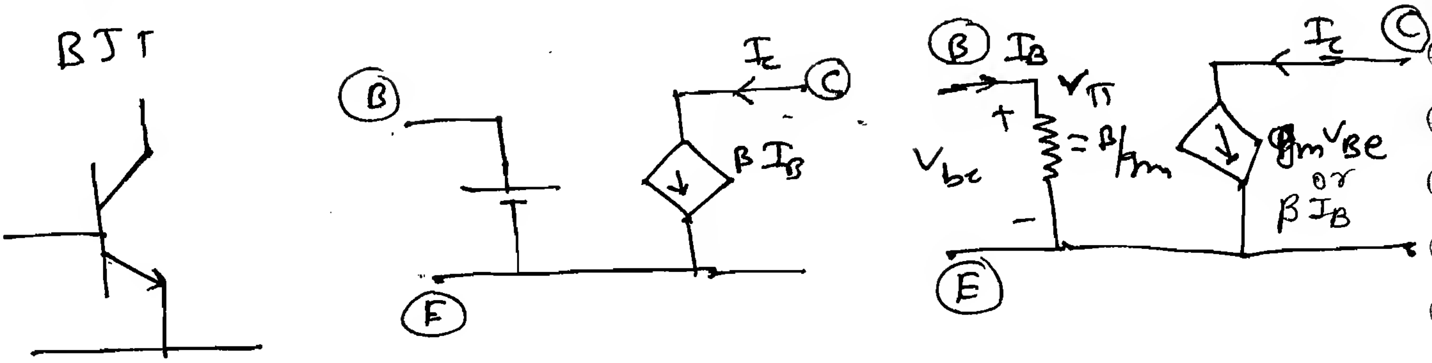


4. Diode
(small signal)

$$r_d = \frac{V_t}{I_{DC}}$$



5. BJT



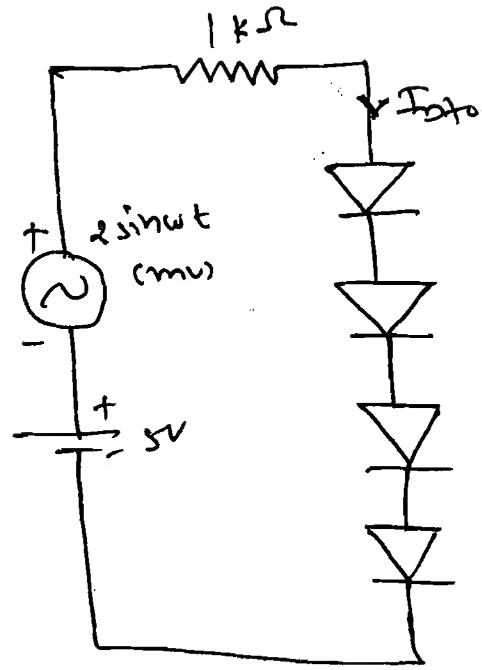
$$I_c = g_m V_{be} \quad , \quad V_{be} = I_B r_\pi$$

$$\therefore \; r_\pi = \frac{V_{be}}{I_B} = \frac{I_c}{g_m \times I_B}$$

$$I_c = \beta I_B$$

$$\therefore \; \boxed{r_\pi = \beta / g_m}$$

☆ Find the total Diode current if $V_t = 25mV$ and forward drop $V_D = 0.7$ volts.

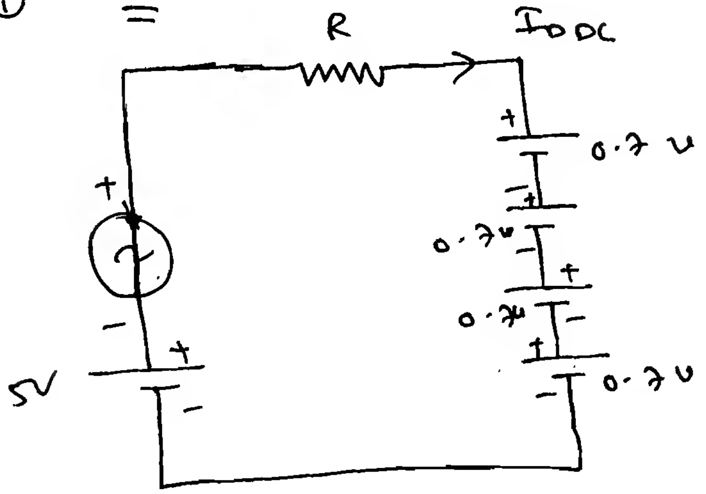


NOTE:

(i) Diode is 2 terminal / nonlinear / passive device.

(ii) BJT is 3 terminal / nonlinear / active device.

① DC

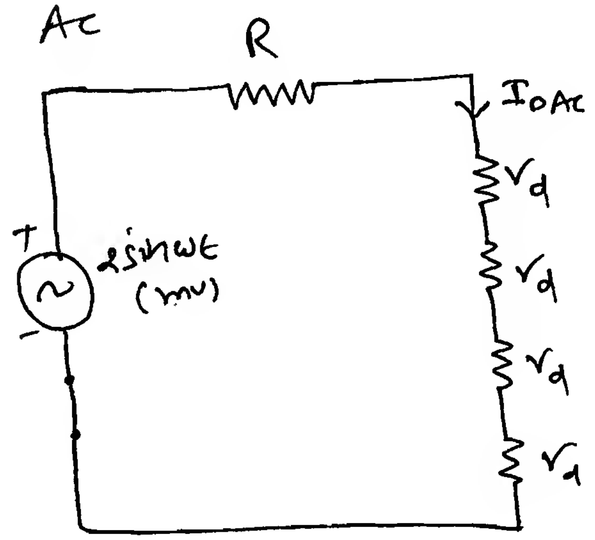


$$I_{DDC} = \frac{5 - (4 \times 0.7)}{1K}$$

$$I_{DDC} = 5 - 2.8 \text{ mA}$$

$$I_{DDC} = 2.2 \text{ mA}.$$

② AC



$$r_d = \frac{V_t}{I_{DDC}}$$

$$r_d = \frac{25}{2.2} = 11.36\,\Omega.$$

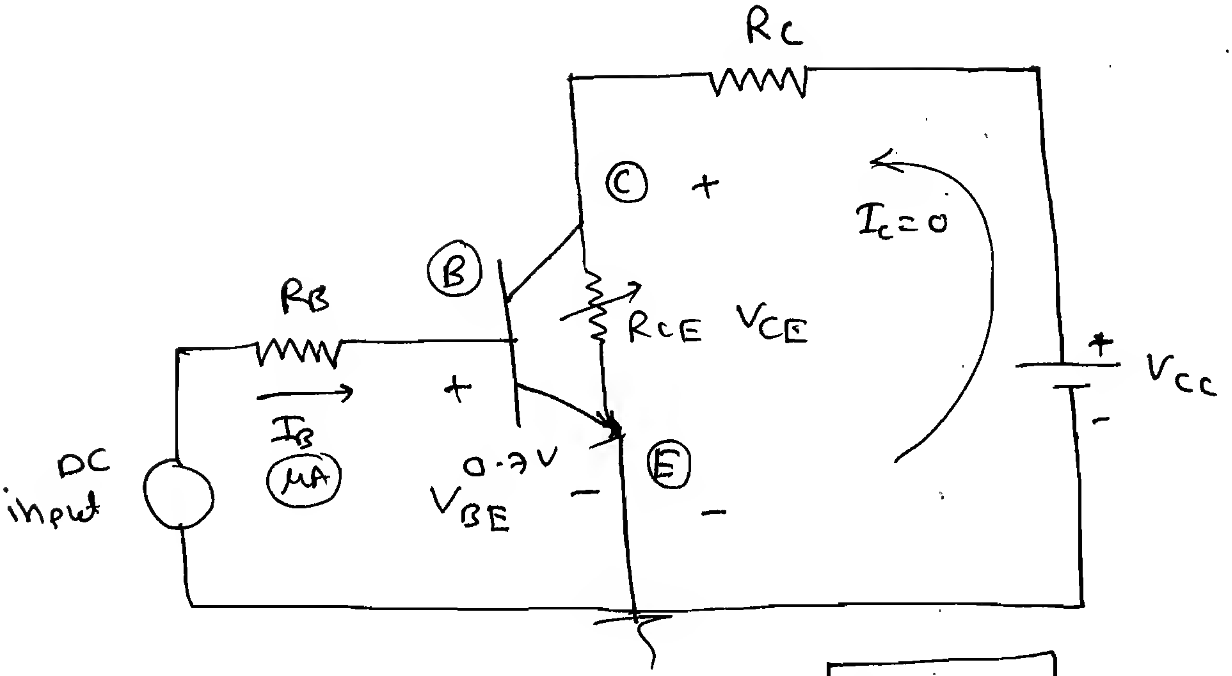
$$I_{DAC} = \frac{2 \sin \omega t}{4(11.36) + 1K}.$$

$$I_{DAC} = 1.913 \sin\omega t \text{ mA}.$$

$$I_{DAC} = 1.913 \sin \omega t \text{ mA}.$$

$$\boxed{I_{D total} = I_{DDC} + I_{DAC} = 2.2 + 1.913 \sin \omega t \text{ mA.}}$$

☆ BJT and its region of operation:



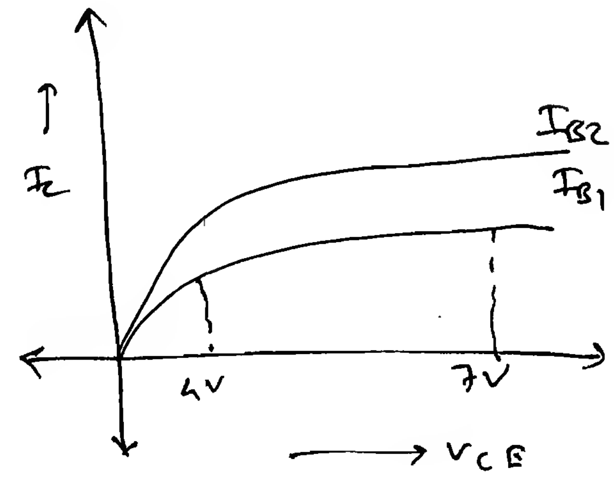
$\boxed{\beta I_B = I_C}$ (mA)

→ I_C is controol by I_B form input side.

$\therefore \quad I_C = \dfrac{V_{CC}}{R_C + \cancel{R_{CE}}} = 0$ Cut off

V_{CC}	I_C	V_{CE}	$R_{CE} = \dfrac{V_{CE}}{I_C}$
5	1m	4V	4K
6	1m	5V	5K
7	1m	6V	6K
8	1m	7V	7K

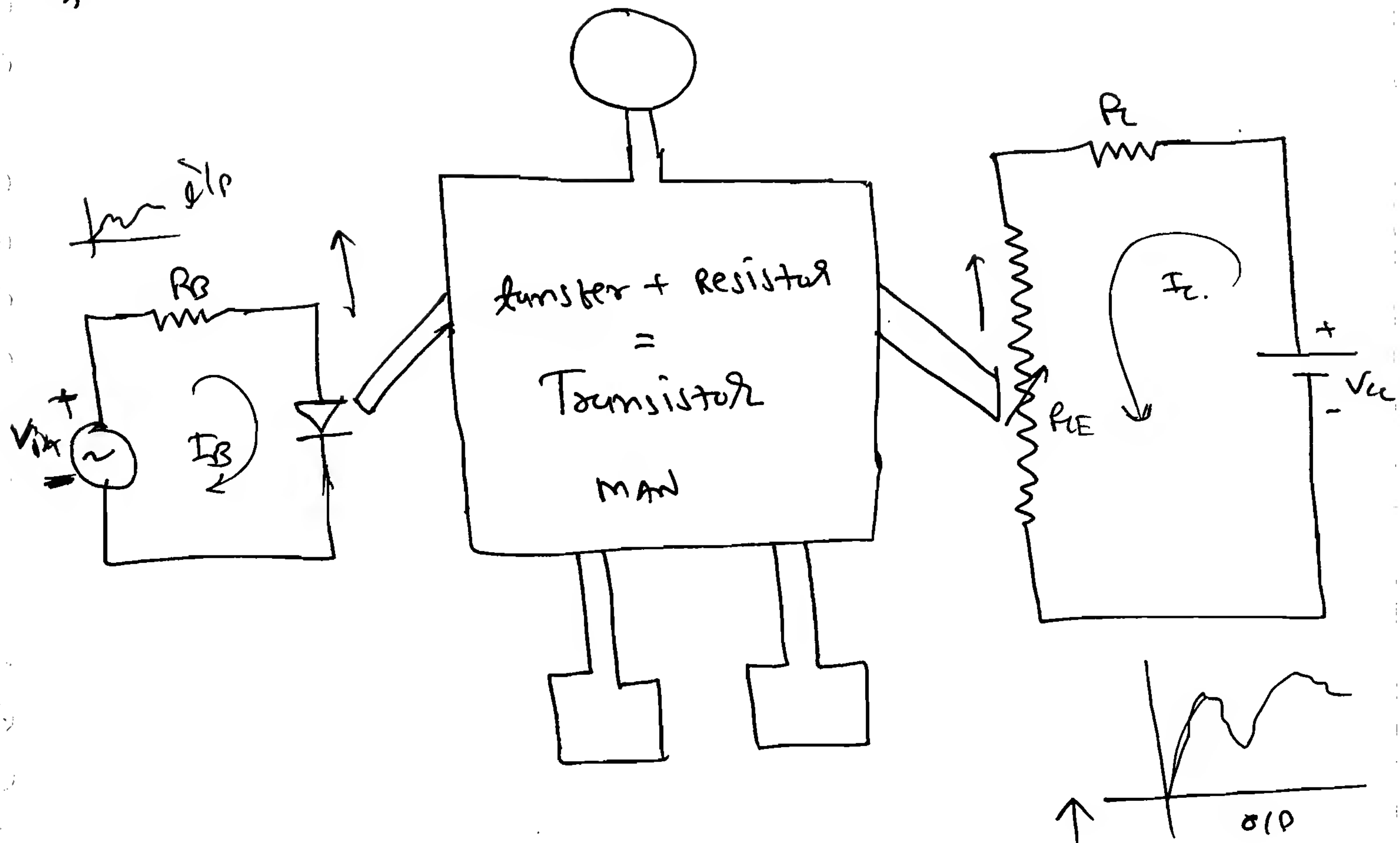
$R_C = 1k$



→ I_C is only change when I_B or R_B will change.

→ So, BJT is current control current source device.

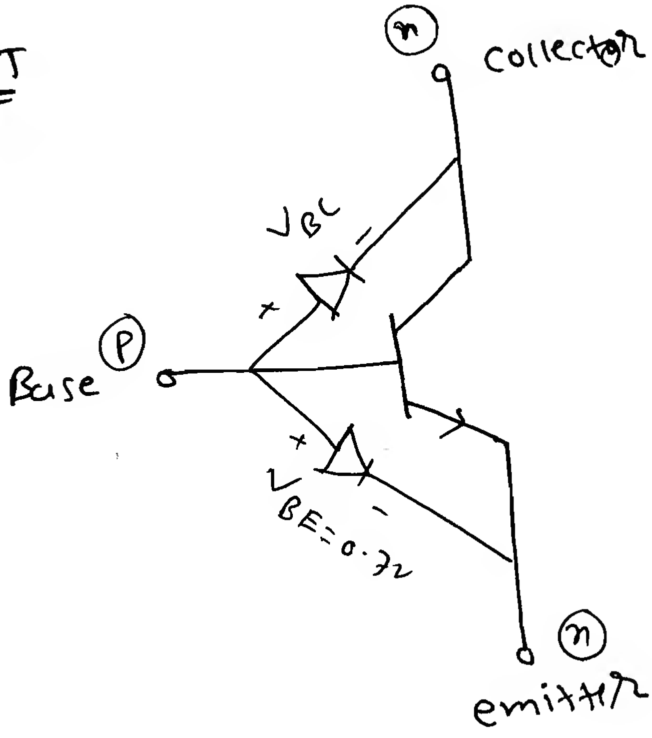
*



If $I_B \uparrow \Rightarrow R_{CE} \downarrow \Rightarrow I_C \uparrow$

If $I_B \downarrow \Rightarrow R_{CE} \uparrow \Rightarrow I_C \downarrow$.

BJT

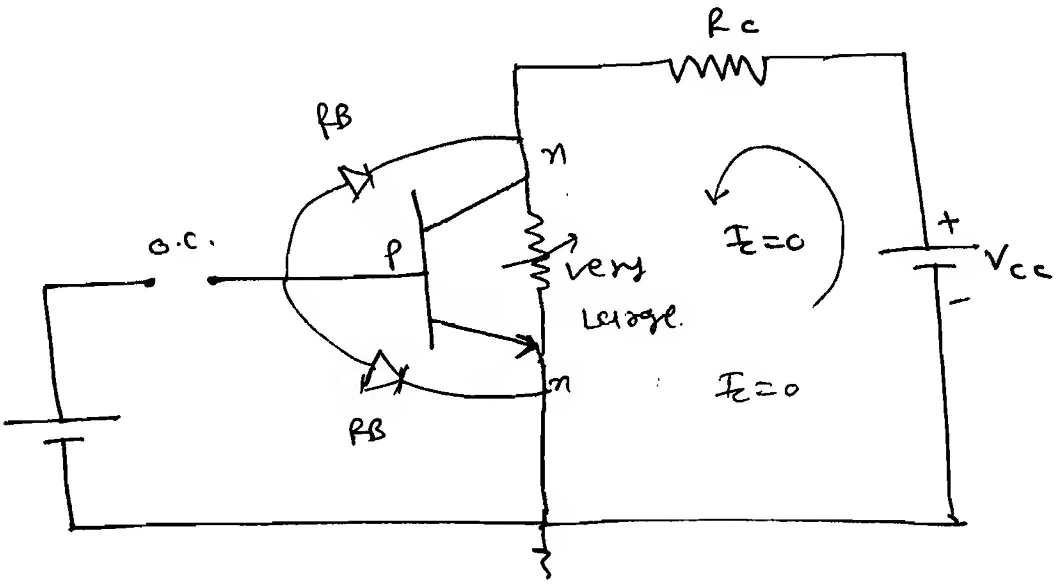


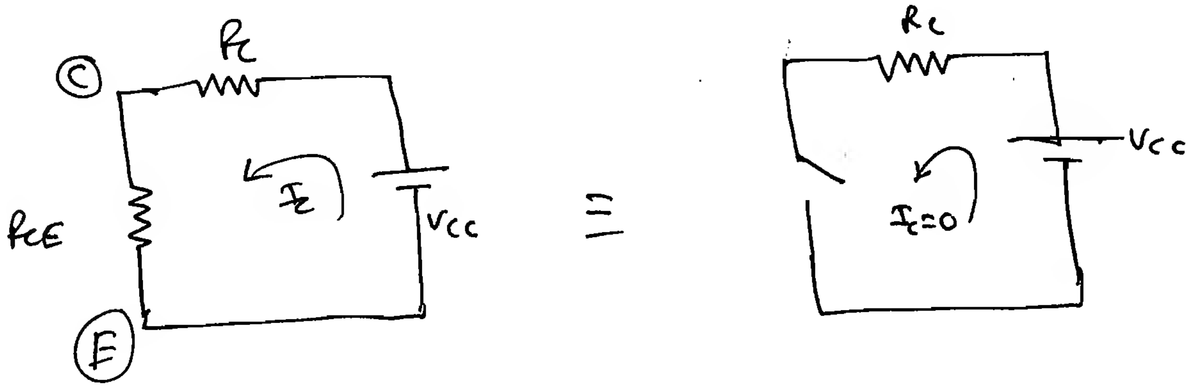
BJT is a controlled OFF switch which is controlled from input side.

*

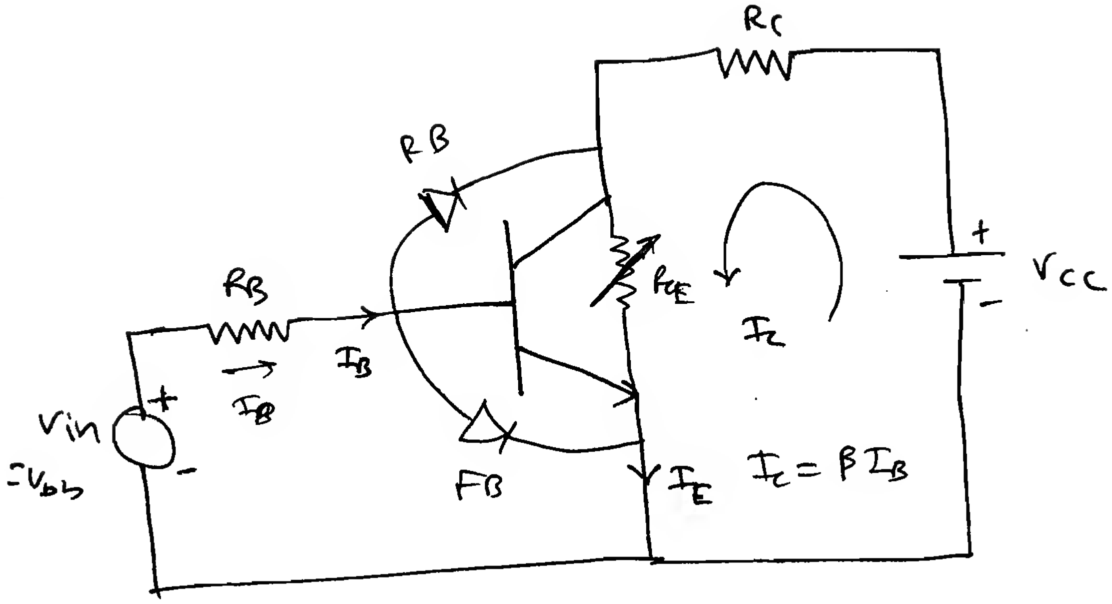
	Emitter-Base Jun.	Collector-Base junction
1. Cut off	$V_{BE} < 0.6\,V$ RB	$V_{BE} < 0.6\,V$ RB
2. Inverse Active	$V_{BE} < 0.6\,V$ RB	$V_{BC} > 0.6\,V$ FB
3. Active	$V_{BE} \geq 0.6\,V$ FB	$V_{BC} < 0.6\,V$ RB
4. Saturation	$V_{BE} \geq 0.6\,V$ FB	$V_{BC} \geq 0.6\,V$ FB

1. Cut-off :

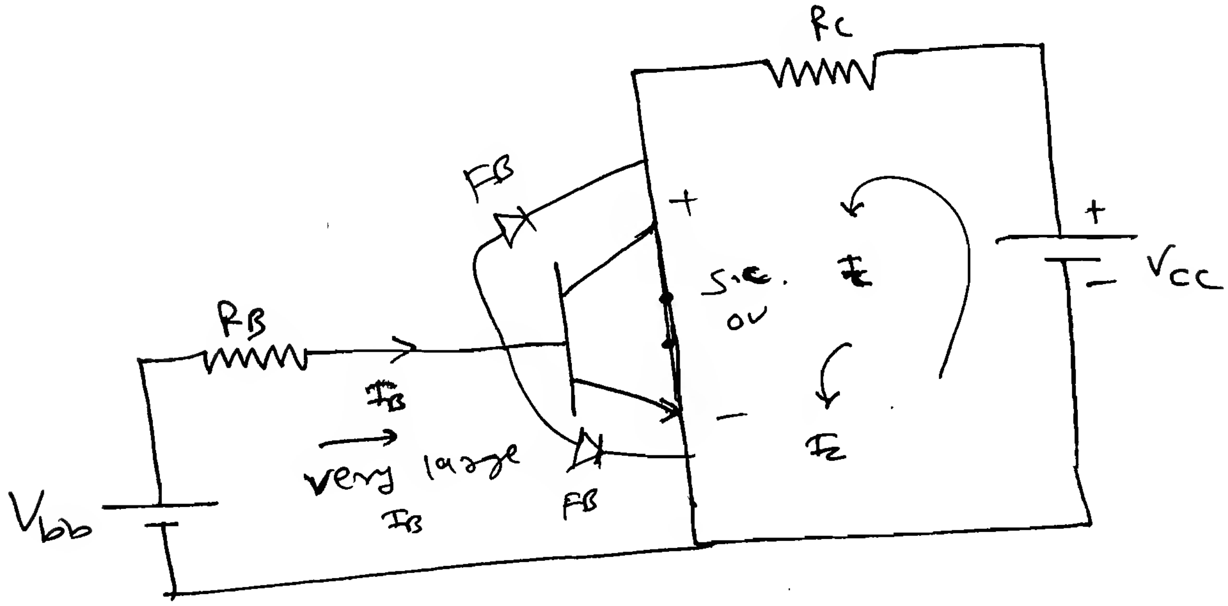




2. Active



3. Saturation:



$|I_B| > |I_B|_{active}$.

$\therefore |I_B| > \left|\frac{I_C}{\beta_{active}}\right|$

$\therefore \beta_{active} > \left|\frac{I_C}{I_B}\right|$.

$\therefore \boxed{\beta_{forced} < \beta_{active}}$.

I_B is very large
⇓
No effect on I_C.

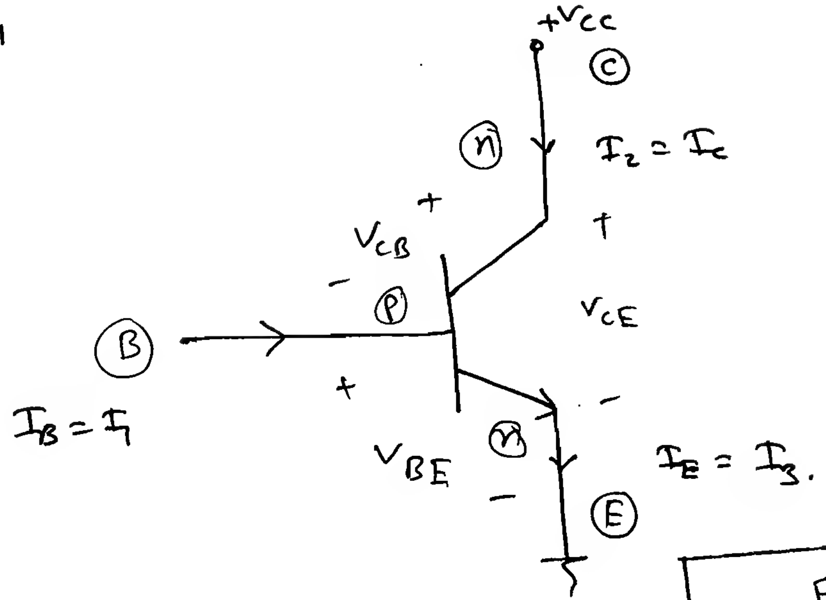
Resistance ⇒ BJT

$\propto$ — cut off
0 — saturation

Active region for Amp.
Cutoff region for switches.

* Solving BJT problem:

① NPN



For npn

Active: $V_{BE} \rightarrow$ Forward, $CB \rightarrow$ Reverse

it is

$V_{CE} > 0.2\,V$

KCL, $I_1 + I_2 = I_3$.

$\therefore \quad I_E = I_B + I_c$.

KVL, $-V_{BE} - V_{CB} + V_{CE} = 0$.

$\therefore \quad V_{CE} = V_{BE} + V_{CB}$.

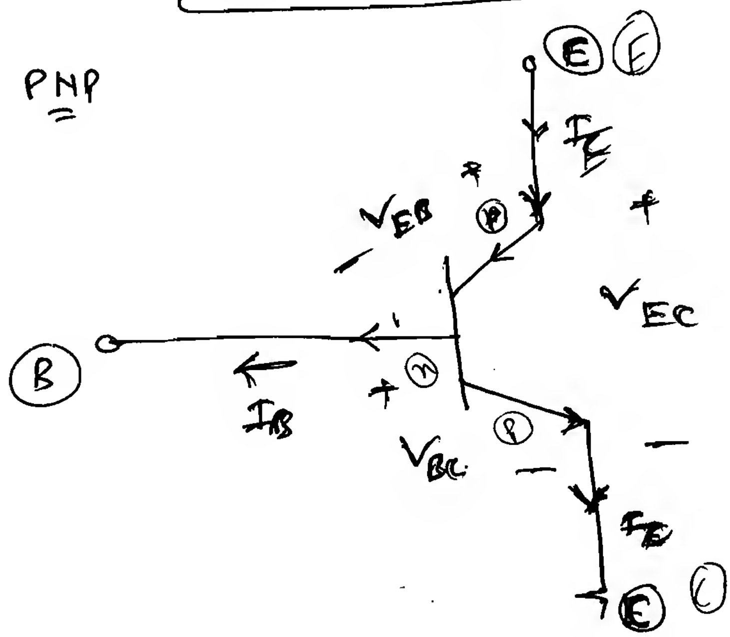
PNP,

$CB \Rightarrow$ Forward.

$BE \Rightarrow$ Reverse.

$V_{EC} > 0.2$.

② PNP

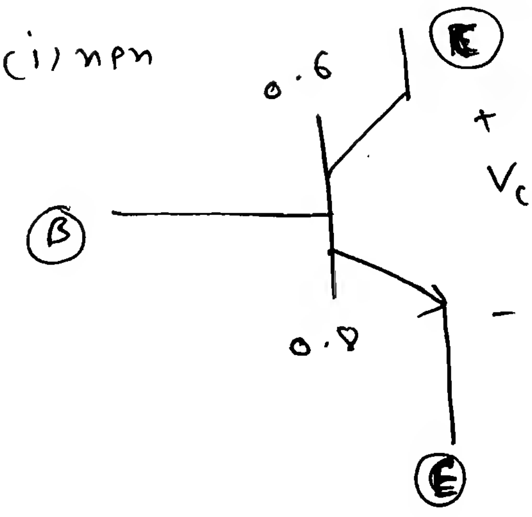


KVL,

$$\boxed{V_{BC} + V_{EB} - V_{EC} = 0}$$

① Active Condition:

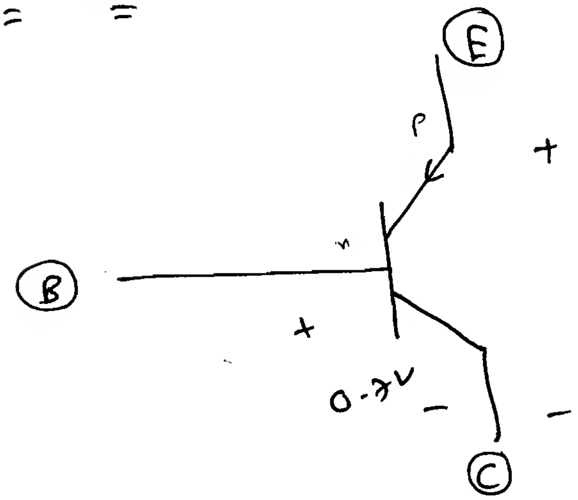
(i) npn



$V_{CE} > 0.2\ V \Leftarrow$ Prove

$I_C = \beta I_B$ assume

(ii) pnp:



$V_{EC} > 0.2 \Leftarrow$ prove

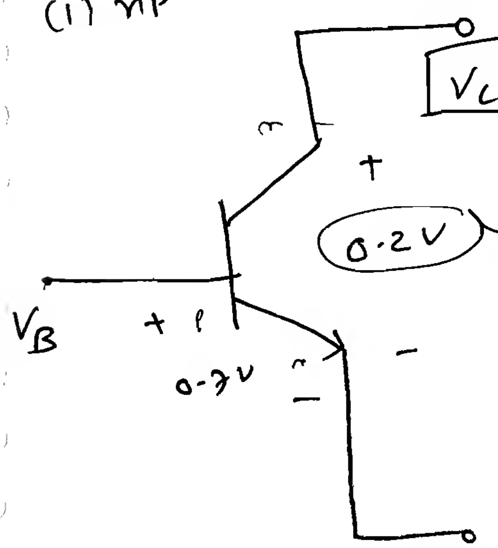
$I_C = \beta I_B$ assume

② Saturation Condition:

(i) npn

$V_C = V_B - 0.7 + 0.2V$

$\boxed{V_C = V_B - 0.5V}$

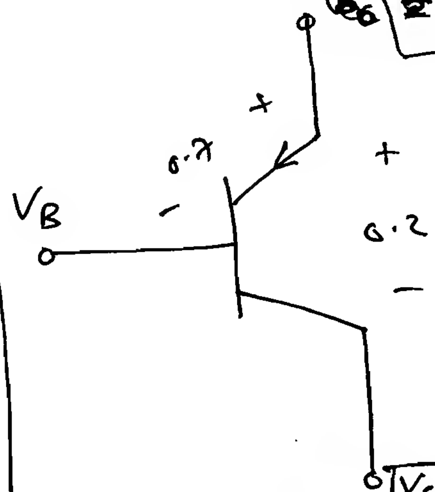


0.2V → assume

$\boxed{V_E = V_B - 0.7V}$

(ii) pnp

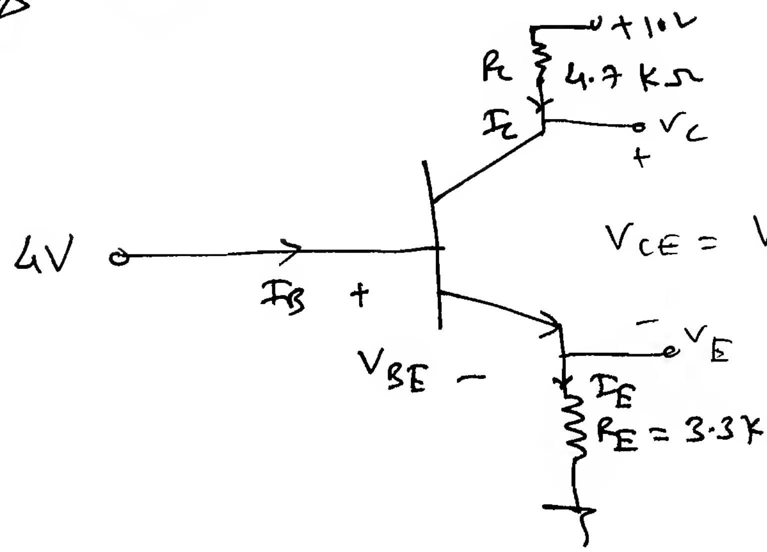
$\boxed{V_E = V_B + 0.7}$



$\boxed{V_C = V_B + 0.5V}$

Prove $\beta_{forced} < \beta_{active}$

Ex-1 Find All node Voltage and Branch current. take $\beta = 100$.



$V_{CE} = V_C - V_E$

Ans:-

$$V_E = 4 - V_{BE}$$

$$\therefore V_E = 4 - 0.7$$

$$\boxed{V_E = 3.3V}$$

$$\therefore I_E = \frac{V_E}{R_E}$$

$$\therefore I_E = \frac{3.3}{3.3K}$$

$$\boxed{I_E = 1 \ mA}$$

$$\therefore I_E = I_C + I_B$$

$$\therefore I_E = \beta I_B + I_B$$

$$\therefore I_E = (\beta + 1) I_B$$

$$I_C = \beta I_B$$

$$\therefore \frac{I_C}{I_E} = \frac{\beta}{\beta + 1}$$

$$I_c = \frac{\beta}{\beta+1} \cdot I_E$$

$$\therefore I_c = \frac{100}{101} \cdot 1mA$$

$$\therefore \boxed{I_c = 0.9909 \text{ mA}}$$

$\rightarrow$ $V_c = 10 - I_c R_c$

$$= 10 - (0.9909m) \times (4.7 \times 1000)$$

$$\therefore \boxed{V_c = 5.346V}$$

$$\therefore V_{CE} = V_c - V_E \qquad (\because npn)$$

$$\therefore V_{CE} = 5.346 - 3.3$$

$$\boxed{V_{CE} = 2.046} > 0$$

So, transistor is in active condition.

<u>Procedure:</u>

V_E

$\downarrow$

I_E

$\downarrow$

I_c

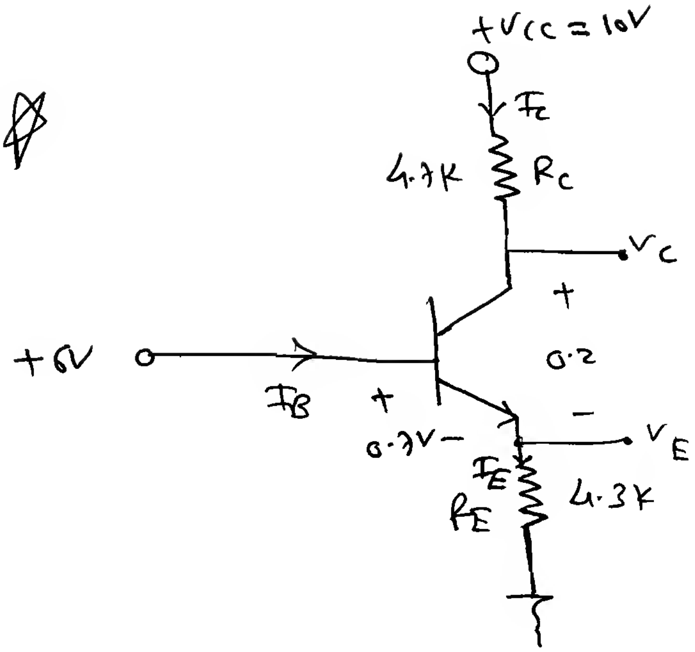
$\downarrow$

V_c

$\downarrow$

Check: V_{CE}.

Ex-2



Ans:

$$V_E = 6 - 0.7V$$

$$\boxed{V_E = 5.3V}$$

$$\therefore I_E = \frac{V_E}{R_E} = \frac{5.3}{4.3}.$$

$$\therefore \boxed{I_E = 1.2325 \text{ mA}}$$

$$\therefore I_c = \frac{\beta}{\beta+1} I_E$$

$$\therefore I_c = \frac{100}{101} \times 1.2325 \text{ mA}$$

$$\therefore \boxed{I_c = 1.2203 \text{ mA}}$$

$$\therefore V_c = 10V - I_c R_c$$

$$= 10 - (1.2203m \times 4.7K).$$

$$\therefore \boxed{V_c = 4.26 V}$$

$$\therefore V_{CE} = V_c - V_E = 4.26 - 5.3 < 0.2$$

$\therefore$ ~~VCEA~~

So, transistor is not in active.

Now, Let, $V_{CE} = 0.2$. and we will find β_{forced}.

$\therefore V_E = 6 - V_{BE}$

$\therefore V_E = 6 - 0.7 = 5.3V.$

$\therefore \boxed{V_E = 5.3V.}$

$V_{CE} = 0.2$

$\therefore V_C - V_E = 0.2.$

$\therefore \boxed{V_C = 5.5V.}$

$\therefore I_C = \dfrac{V_{CC} - V_C}{R_C}.$

$\therefore I_C = \dfrac{10 - 5.5}{4.7}$

$\therefore \boxed{I_C = 0.957 mA}.$

$I_E = \dfrac{V_E}{R_E}$

$I_E = 1.2325.$

$\therefore I_B = I_E - I_C$

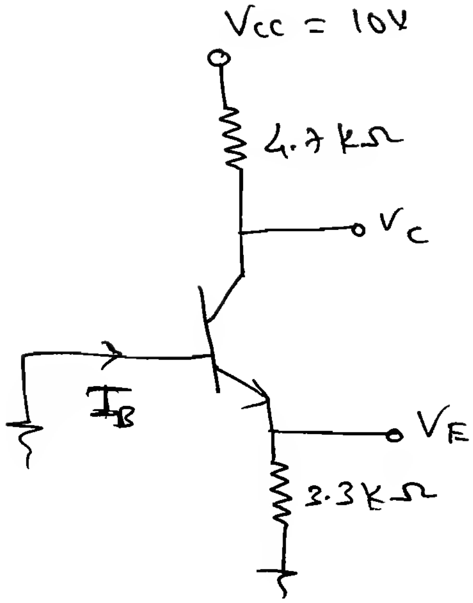
$\boxed{I_B = 0.275 \cdot mA}$

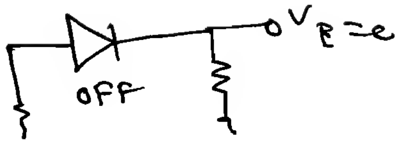
$\therefore \beta_{forced} = \dfrac{I_C}{I_B}$

$\boxed{\beta_{forced} = 3.473 < \beta_{active}.}$

So, transistor is in saturation region.

Ex 3





Ans:

$V_E = 0$

$I_E = 0$

$I_C = 0.$

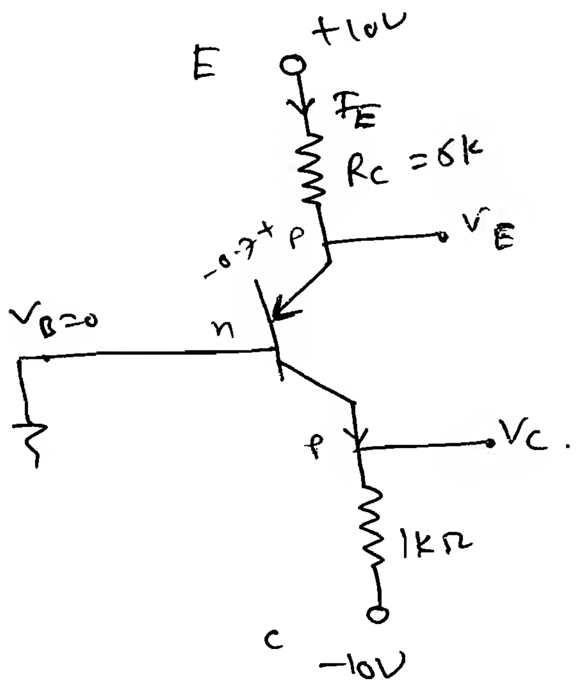
∴ $V_C = V_{CC} - I_C R_C$

∴ $V_C = V_{CC} = 10V$

∴ $\boxed{V_C = 10V.}$

So, transistor is in cutoff.

Ex 4



$\therefore V_E = V_B + V_{BE}.$

$\therefore V_E = 0 + 0.7\,V$

$\boxed{V_E = 0.7V}$

$\therefore I_E = \dfrac{10 - 0.7}{5k}$

$\therefore \boxed{I_E = 1.86\,mA}$

$\therefore I_C = \dfrac{\beta}{\beta+1} \times I_E$

$\therefore I_C = \dfrac{100}{101} \times 1.86$

$\therefore \boxed{I_C = 1.84\,mA.}$

$\therefore V_C = I_C R_C - 10V.$

$V_C = (1.84) - 10V.$

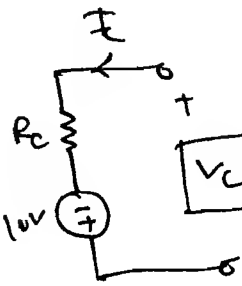
$\therefore \boxed{V_C = -8.16\,\cancel{mA}}$

$V_{EC} = V_E - V_C$

$\therefore V_{EC} = 0.7 - (-8.6)$

$\therefore V_{EC} = 8.76 > 0.2V$

So, in active region.



$\boxed{V_C = I_C R_C - 10.}$

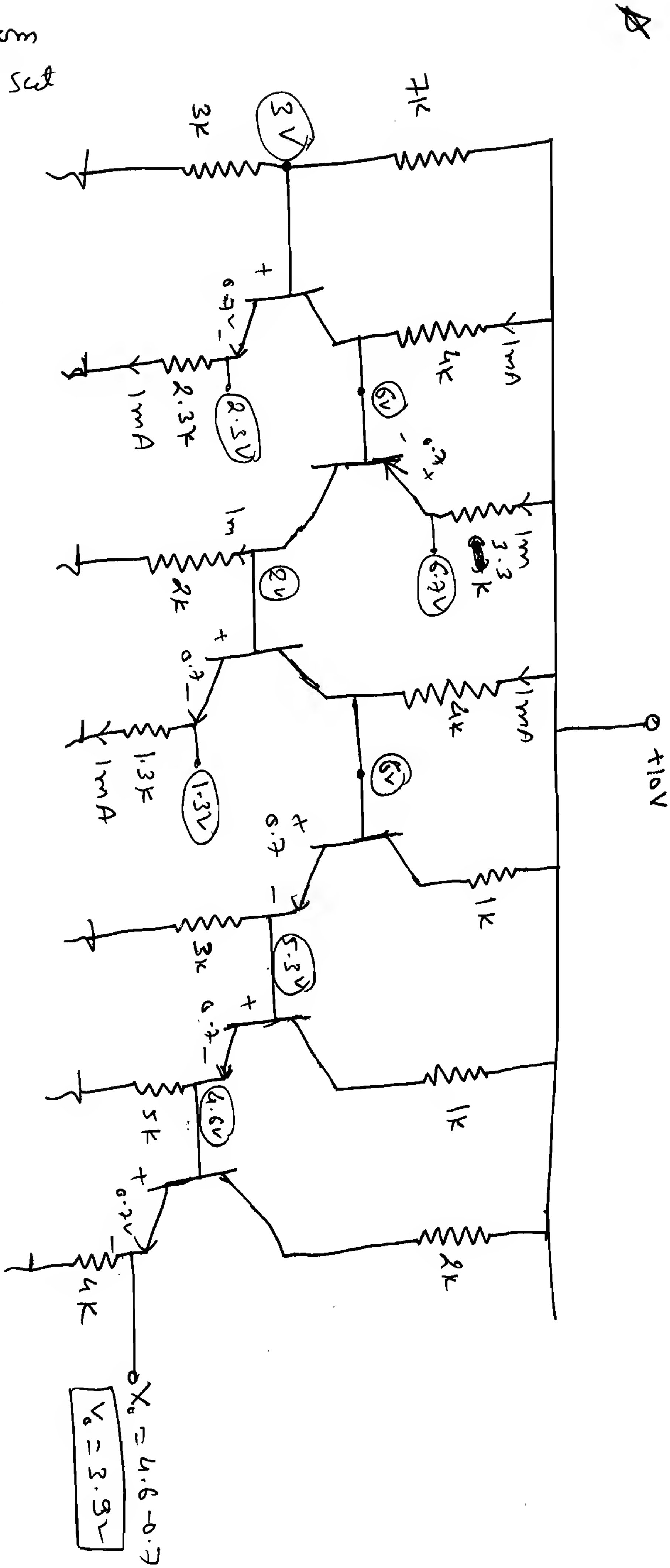
* To make BJT from ~~sat~~ ~~**~~ active to sat following two ways can be applicable:

(a) $\frac{I_C \downarrow}{I_B \uparrow} = \beta_{forced} < \beta_{active}$ $\quad R_C \uparrow$, $V_{bb} \uparrow$

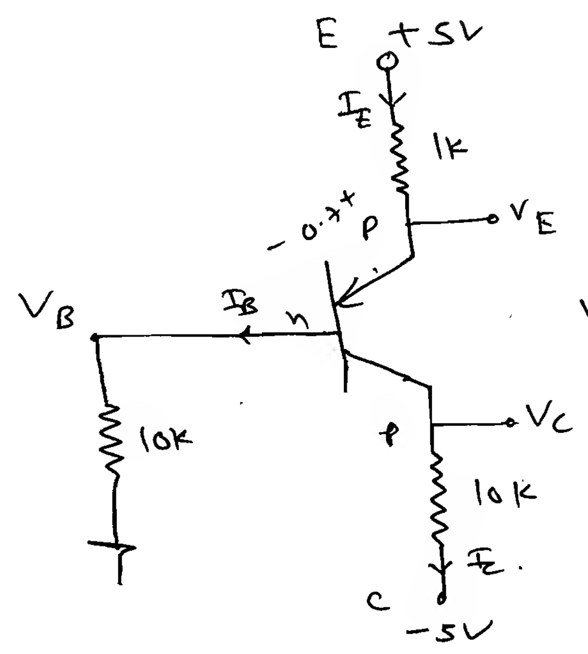
→(i) I_C should be decrease ~~increase~~ and it can be achive by increasing value of R_C:

$R_C >>$ Large.

(ii) By increasing V_{bb} I_B can be increased which in turn reduce the β_{forced}.



Ex-4 Calculate the All node voltages and branch current $\beta = 100$ and it is in saturation.



$V_{EC} = 0.2V$

$$\boxed{V_E = V_B + 0.7 V}$$

$$V_C = V_E - V_{EC}$$

$$\therefore V_C = V_B + 0.7 - 0.2$$

$$\boxed{V_C = V_B + 0.5 V}$$

$\longrightarrow$ $I_E = I_B + I_C$.

$$\therefore \frac{5 - V_E}{1k} = \frac{V_B}{10k} + \frac{V_C + 5V}{10k}.$$

$$\therefore 10(5 - V_B - 0.7) = V_B + V_B + 5 + 0.5$$

$$\therefore 50 - 10V_B - 7 = 2V_B + 5.5$$

$$\therefore 12V_B = 37.5$$

$$\therefore \boxed{V_B = 3.125 V}$$

$$\therefore I_B = V_B / R_B = \frac{3.125}{10k} = 0.3125 mA$$

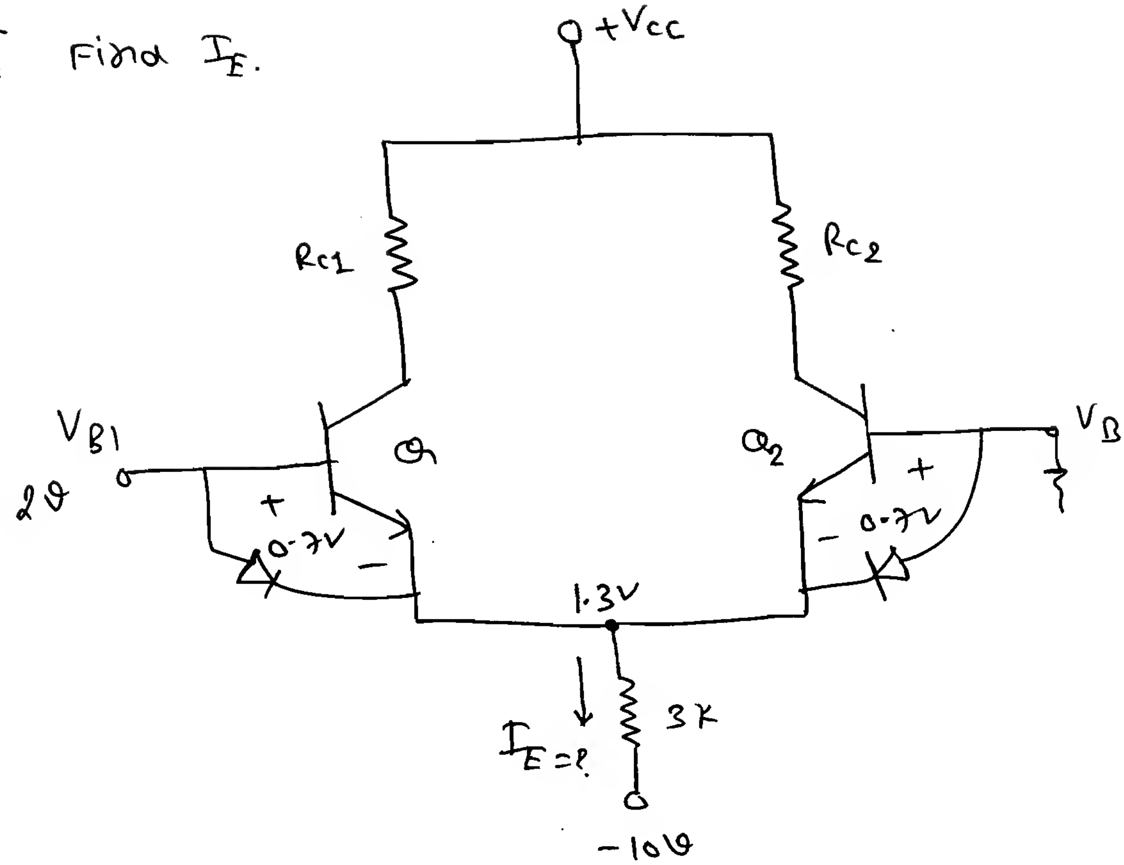
$$\therefore I_C = \frac{3.125 + 5 + 0.5}{10} = 0.86 mA.$$

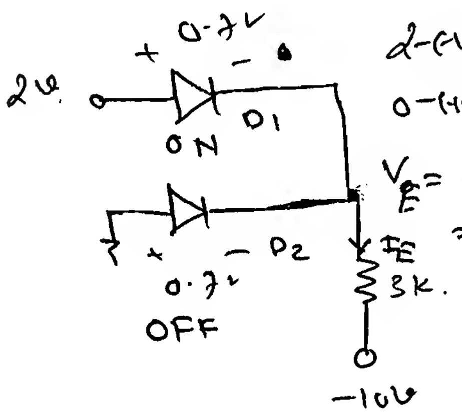
$$\therefore \beta_{forced} = \frac{0.86}{0.3125} = 2.752 < \beta_{active}.$$

So, it is in sat.

$$I_E = I_C + I_B = 1.1725 mA \qquad \boxed{I_E = 1.1725 mA}$$

Ex-5 Find I_E.





$2-(-10)=12$

$0-(-10)=10$

$V_E = 2 - 0.7$
$= 1.3V$

D_1 is on because it experience ~~less~~ more potential difference.

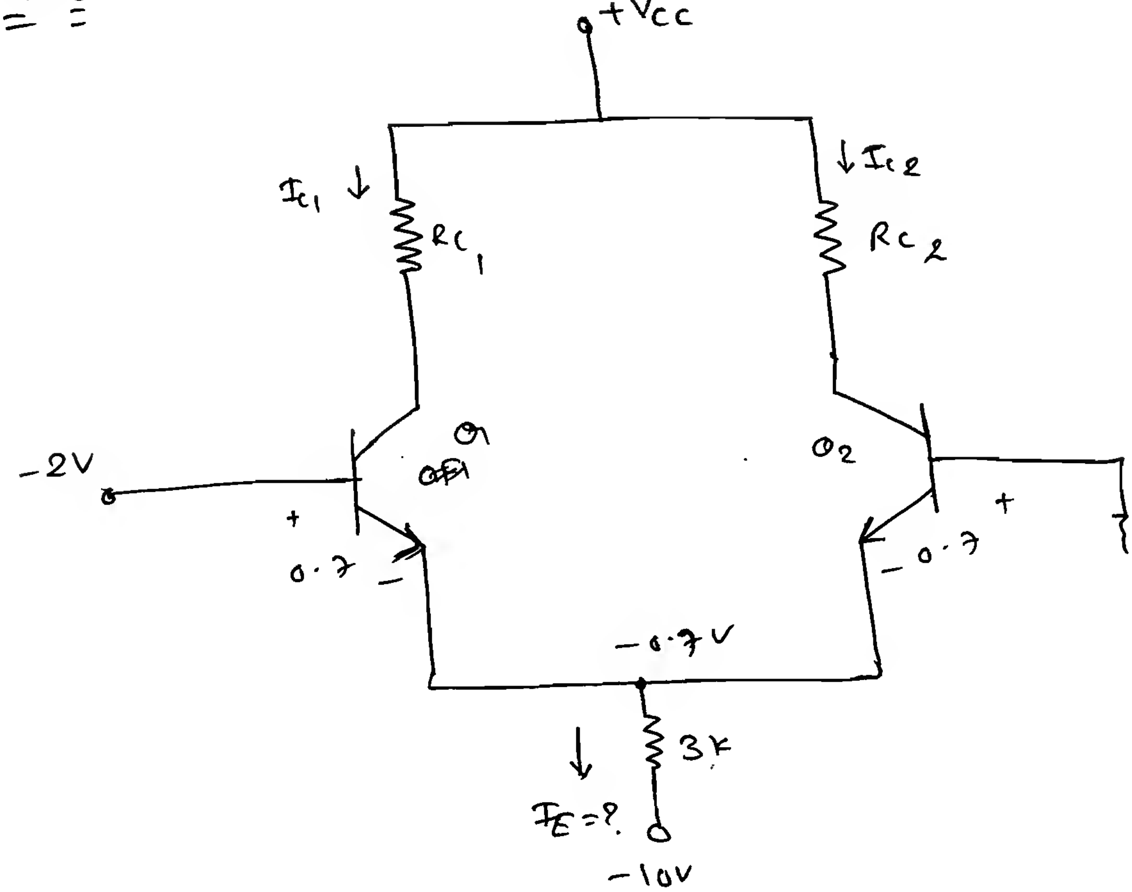
$\rightarrow \quad \therefore \quad I_E = \dfrac{1.3-(-10)}{3K}$

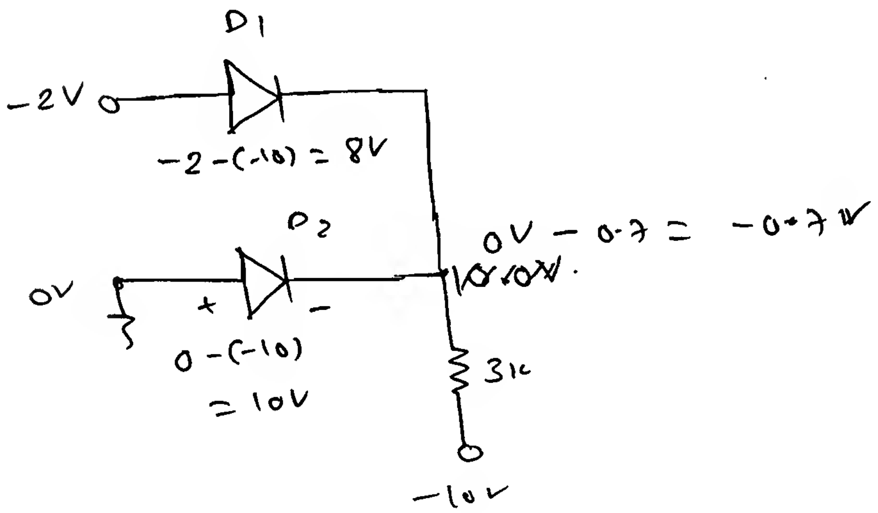
$$\boxed{I_E = 3.76mA}$$

→ Diode in BJT can be on by either

✓ Voltage divider or giving + negative supply.

Ex 2

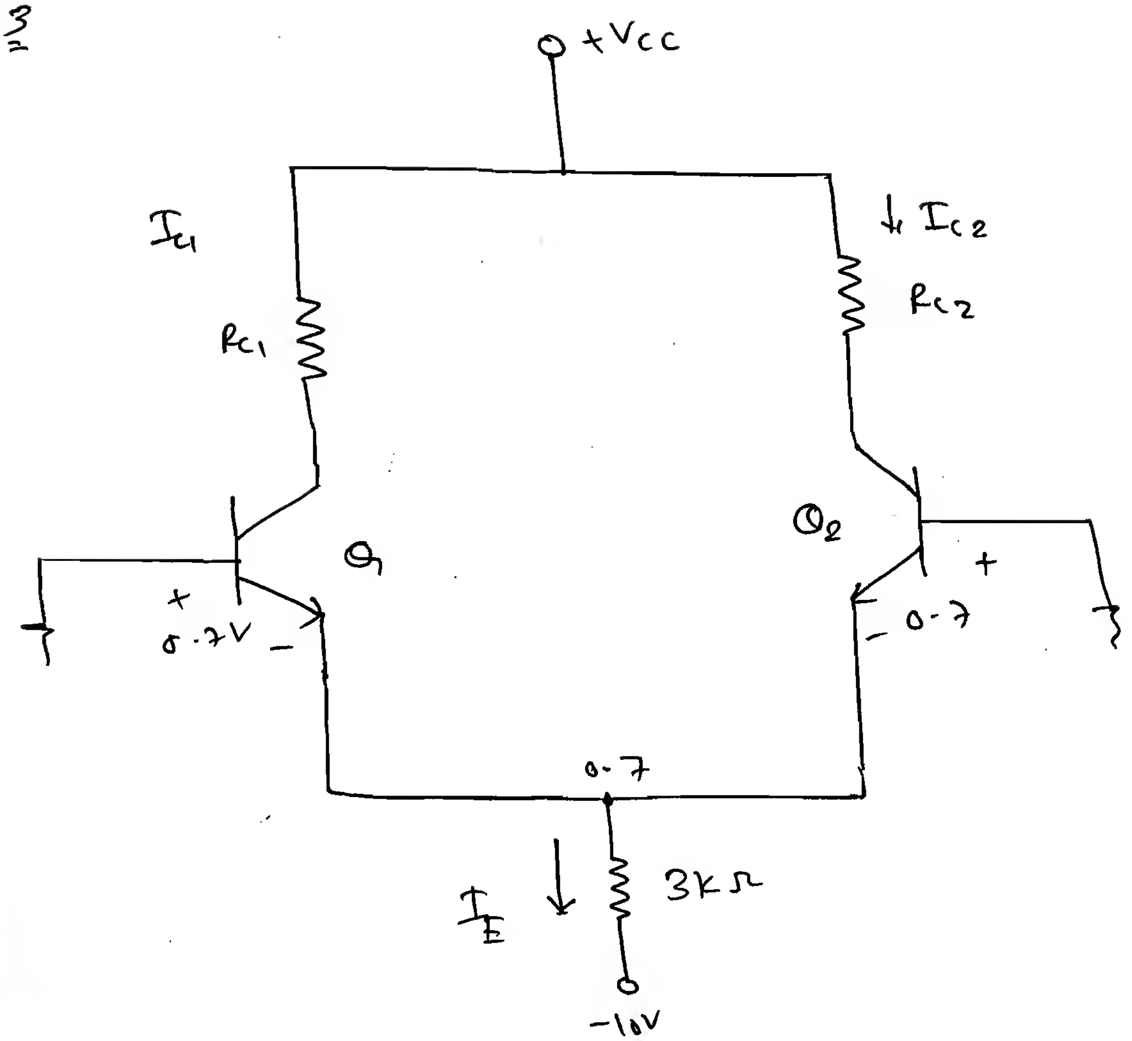


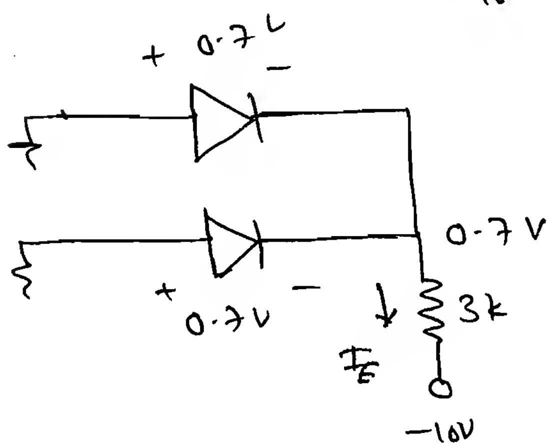


$$\therefore \quad I_E = \frac{-0.7 - (-10)}{3K}$$

$$\therefore \quad \boxed{I_E = 3.1\,mA.}$$

Ex 3





$$\therefore \quad I_E = \frac{0.7-(-10)}{3k} = \frac{10.7}{3k} = 3.567\,mA$$

$$I_{E1} = I_{E2} = I_E$$

$$\therefore \quad 2 I_E = I_E$$

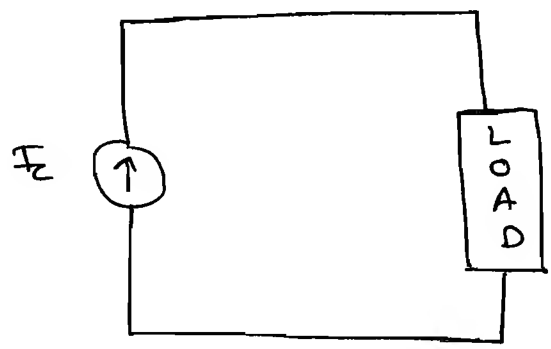
$$\therefore \quad I_{C1} = I_{E2} = I_E/2$$

$$\therefore \quad \boxed{I_{C1} = I_{E2} = 1.78\,mA}$$

Biasing a BJT:

→ The purpose of biasing is to switch on the BJT to work in active region such that the DC collector current remain constant independent of β, Temp. and load variations.

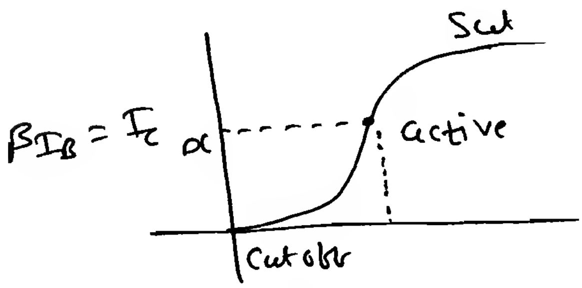
→



$$I_c \neq f\,(\beta,\ \text{temp},\ \text{Load})$$

$$\therefore \boxed{I_c \neq f\,(\beta,\ V_{be},\ V_{ce}).}$$

① β (with R_E).



if β change the $I_c = \beta I_B$ changes.

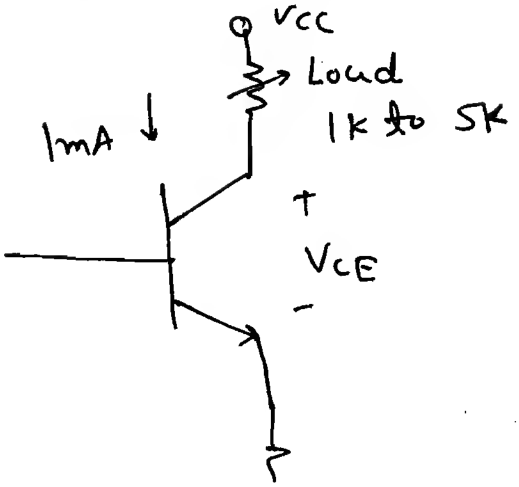
② Temperature:

→ $V_{BE} = -2.5\,\text{m}/°\text{C}$

→ If temp. changes ⇒ V_{BE} changes. this will change I_B and will turn in change the I_c.

③ Load Variations:

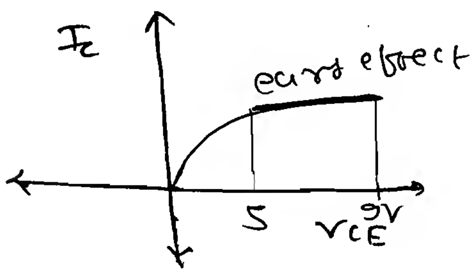
→



$$V_{CE} = V_C - V_E.$$

$$\therefore V_{CE} = V_{CC} - I_C R_C - V_E$$

$$\therefore I_C = \frac{V_{CC} - V_{CE} - V_E}{R_C}$$



if R_C changes

⇓

V_{CE} changes

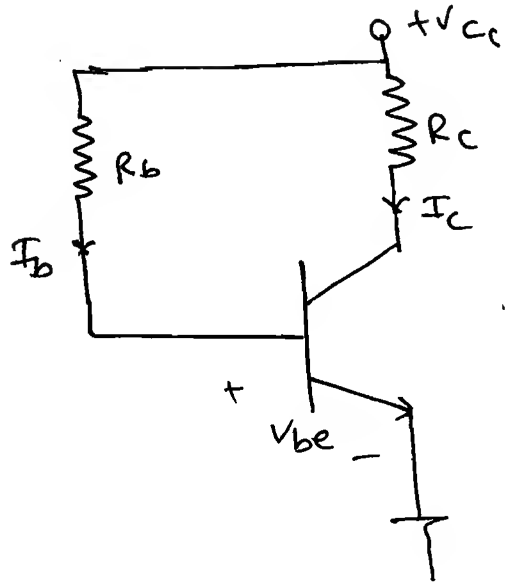
⇓

I_C will change.

→ In order to rid this problem we should make constant current source.

① Fixed Bias / Fixed Base bias:

→



→ $I_B = \dfrac{V_{CC} - V_{BE}}{R_b}$.

$V_{BE} \simeq$ const.

$R_b \simeq$ const.

$\therefore \; I_B =$ const.

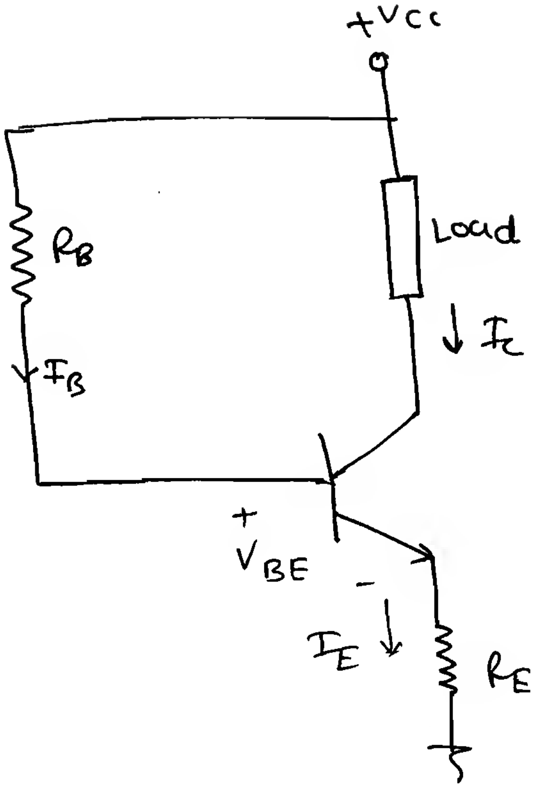
$\therefore \; I_C = \beta I_b = \beta \left[\dfrac{V_{CC} - V_{BE}}{R_B} \right]$.

→ β changes from 50 to 250 for the different specimens of the given transistor type. any ckt which depend of a particular value of β is a bad ckt.

→

without R_E	with R_E
$I_C = \beta I_B$	$I_C = \beta I_B$.
$I_B = K$ = const.	$I_C = K$ = const
$I_C = \beta I_B$.	$\therefore \; I_B = I_C / K$.

→



$$\rightarrow \quad V_{CC} = I_B R_B + V_{BE} + I_E R_E$$

But, $I_E = (\beta+1) I_B$.

$\rightarrow I_B = I_E / \beta+1$.

$$\therefore \quad V_{CC} - V_{BE} = \left(\frac{R_B}{\beta+1} + R_E\right) I_E.$$

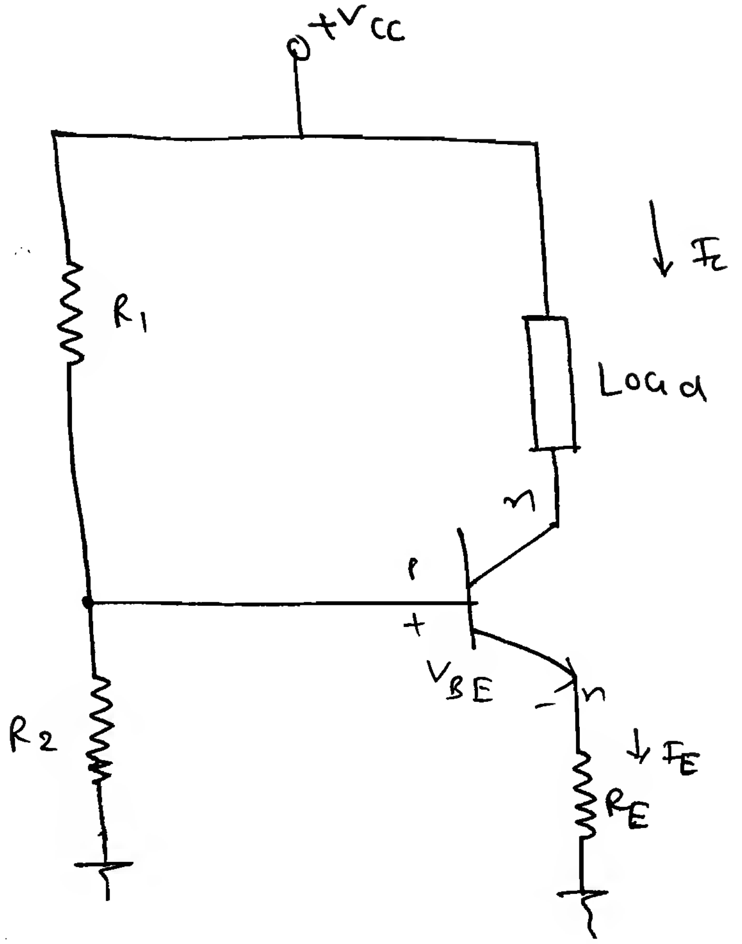
$$\therefore \quad I_E = \frac{V_{CC} - V_{BE}}{R_E + \frac{R_B}{\beta+1}}.$$

Now, choose $\boxed{R_E \gg \frac{R_B}{\beta+1}}$

$$\therefore \quad I_E \simeq I_{DC} = \frac{V_{CC} - V_{BE}}{R_E}.$$

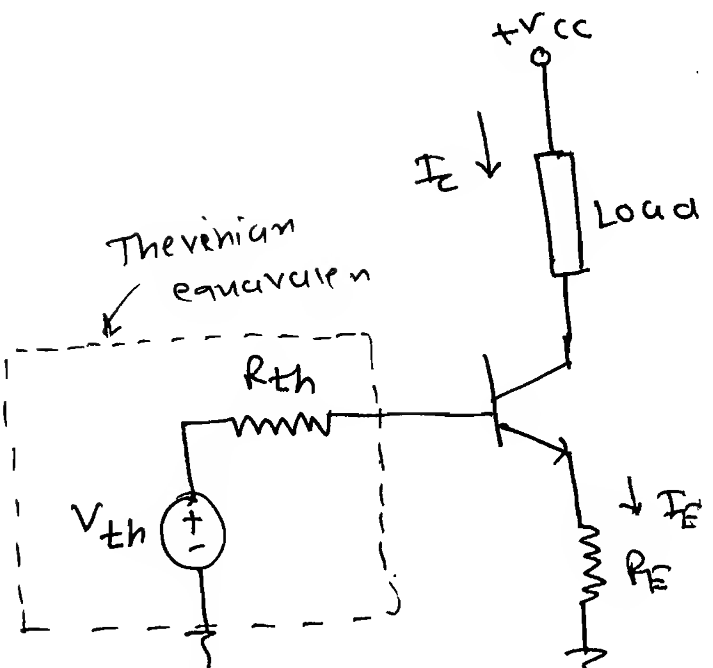
② Voltage divider bias (or)
Self bias (or)
Universal bias.

⇒



→

|||



(neglacting I_B).

$I_B \simeq 0A$

$$V_{th} = \frac{V_{cc} R_2}{R_1 + R_2}$$

$$R_{th} = \frac{R_1 . R_2}{R_1 + R_2} = R_1 || R_2$$

$$\rightarrow \quad V_{th} - V_{BE} - I_B R_B - I_E R_E = 0.$$

$$\therefore \quad I_B = \frac{I_E}{\beta+1}.$$

$$\therefore \quad I_E \left[\frac{R_B}{\beta+1} + R_E \right] = V_{th} - V_{BE}.$$

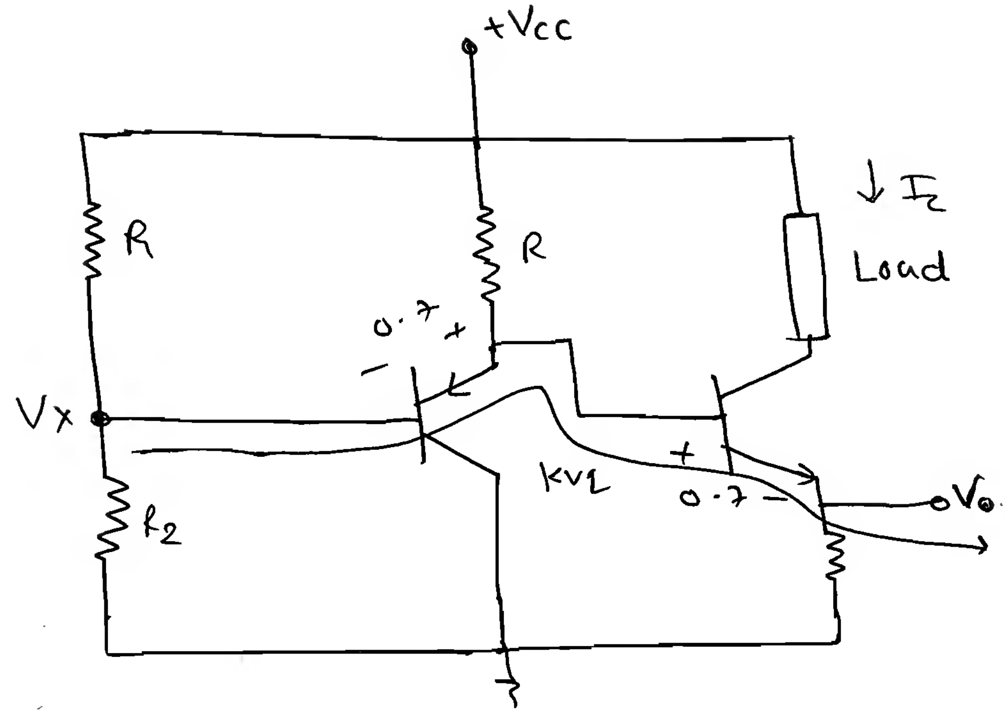
$$\therefore \quad \boxed{I_E = \frac{V_{th} - V_{BE}}{R_E + \frac{R_B}{\beta+1}} \simeq I_{CDC}}$$

$$R_E >> \frac{R_{th}}{\beta+1}.$$

$$\therefore \quad R_E >> \left(\frac{R_1 \cdot R_2}{R_1 + R_2} \right) \times \frac{1}{\beta+1}.$$

$$\therefore \quad \boxed{I_{CDC} = \frac{\frac{V_{CC} R_2}{R_1 + R_2} - V_{BE}}{R_E}}$$

Ex-1



$$\rightarrow \quad V_X = \frac{V_{CC} R_2}{R_1 + R_2}.$$

$$\therefore \quad V_X + 0.7 - 0.7 - V_0 = 0.$$

$$\therefore \quad V_X = V_0 = V_E$$

$$\therefore \quad \boxed{V_E = V_0 = \frac{V_{CC} R_2}{R_1 + R_2} \; v}$$

$$\therefore \quad I_C \simeq I_E = \frac{V_E}{R_E}.$$

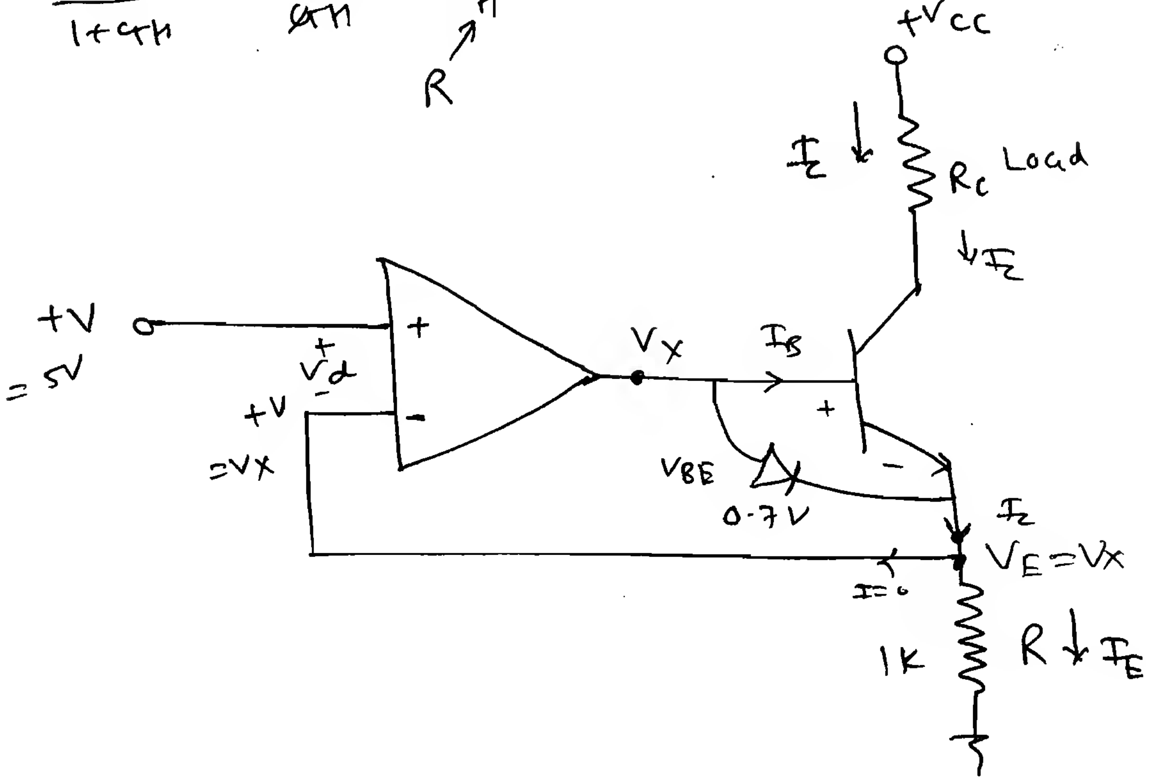
$$\therefore \quad I_C = \frac{\frac{V_{CC} R_2}{R_1 + R_2}}{R_E}$$

$$\therefore \quad \boxed{I_C = \frac{V_{CC} R_2}{(R_1 + R_2) R_E} = V|R.}$$

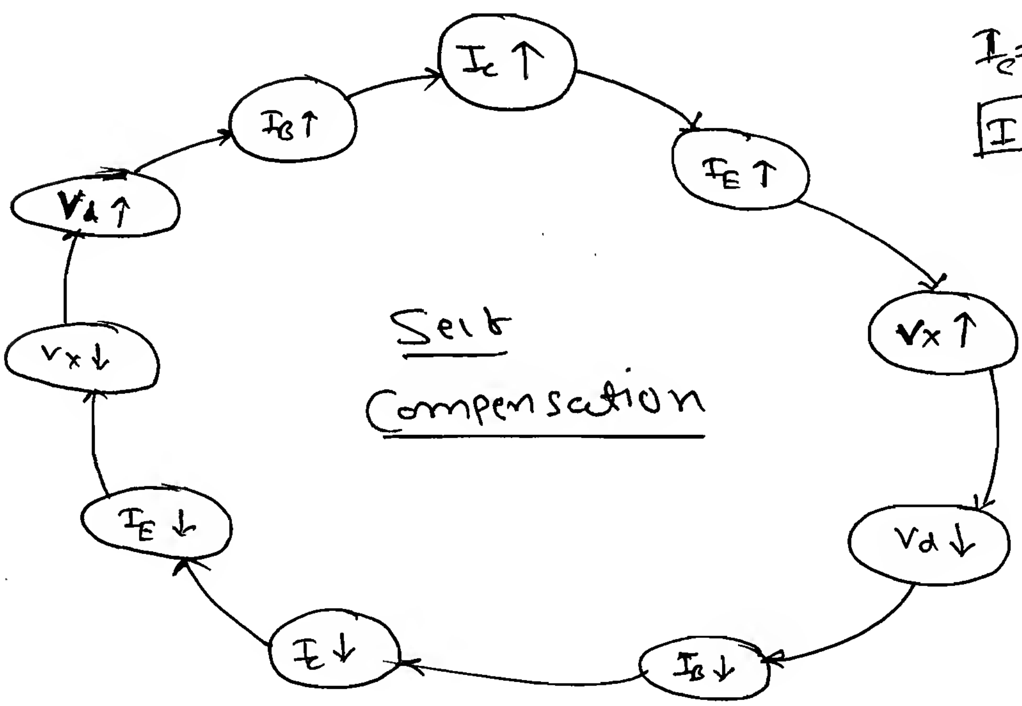
NOTE: Designing a current source with Op-Amp in -ve feedback will totally eliminate the problem of drift.

* $\frac{G}{1+GH} = \frac{G}{GH} = \frac{1}{H}$

R



⇒

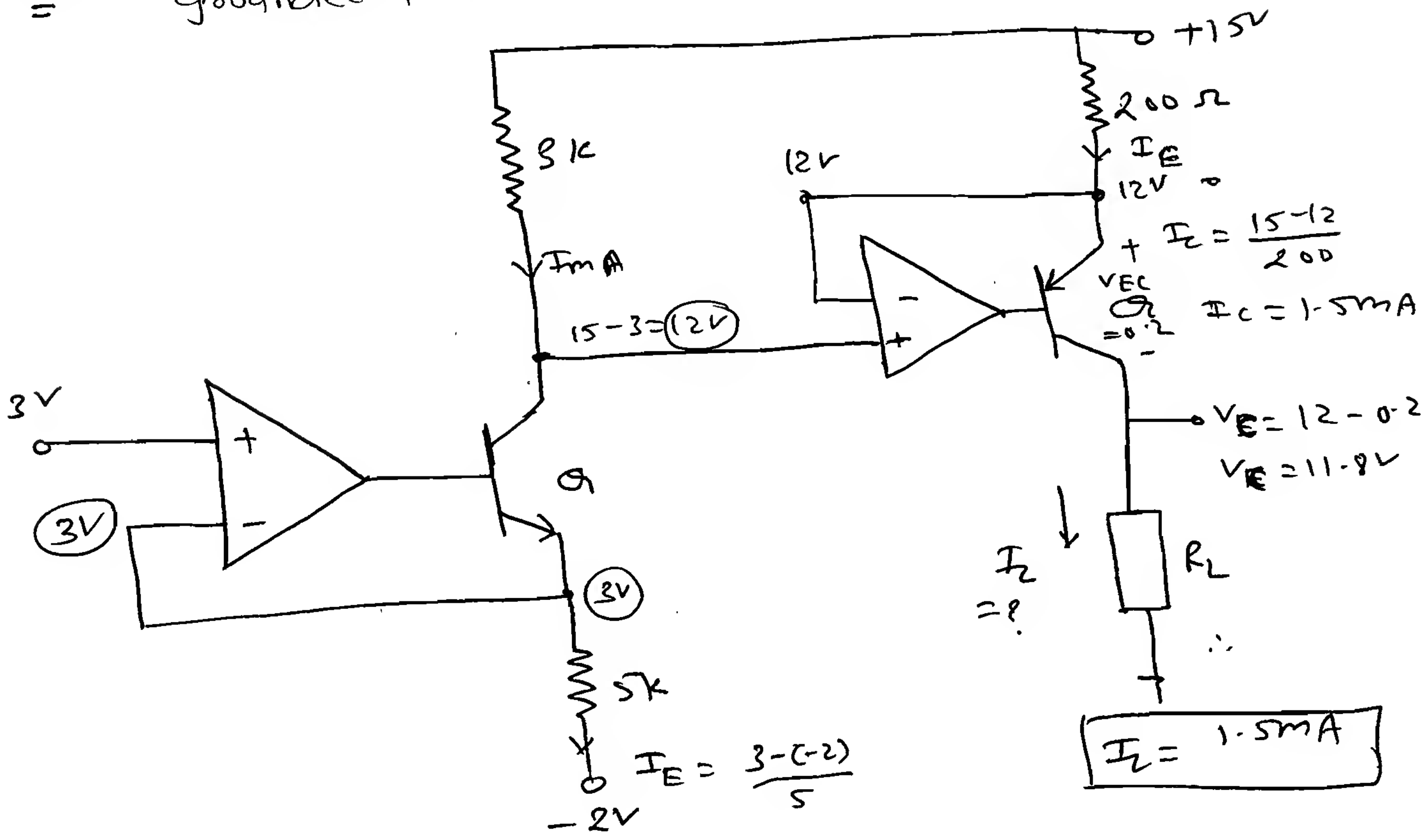


$I_c = 5/1k$

$\boxed{I_c = 5mA}$

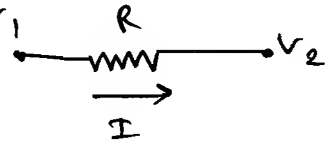
→ Temp. changes but all parameters stable which is because of -ve feed back mechanism provided by non-inverting OP-Amp.

Ex-1 Voltage programmable current source with grounded load.



$I_E = 1mA$

*** NOTE:**



$\Rightarrow \boxed{I = \frac{V_1 - V_2}{R}}$, $\boxed{V_2 = V_1 - IR}$

→ find the minimum value of R_L for the BJT to be in sat. with $V_{EC} = 0.2$.

$\therefore V_E = 12V$

$V_{EC} = 0.2V$

$\therefore V_E - V_C = 0.2$

$\therefore V_C = 12 - 0.2 = 11.8V.$

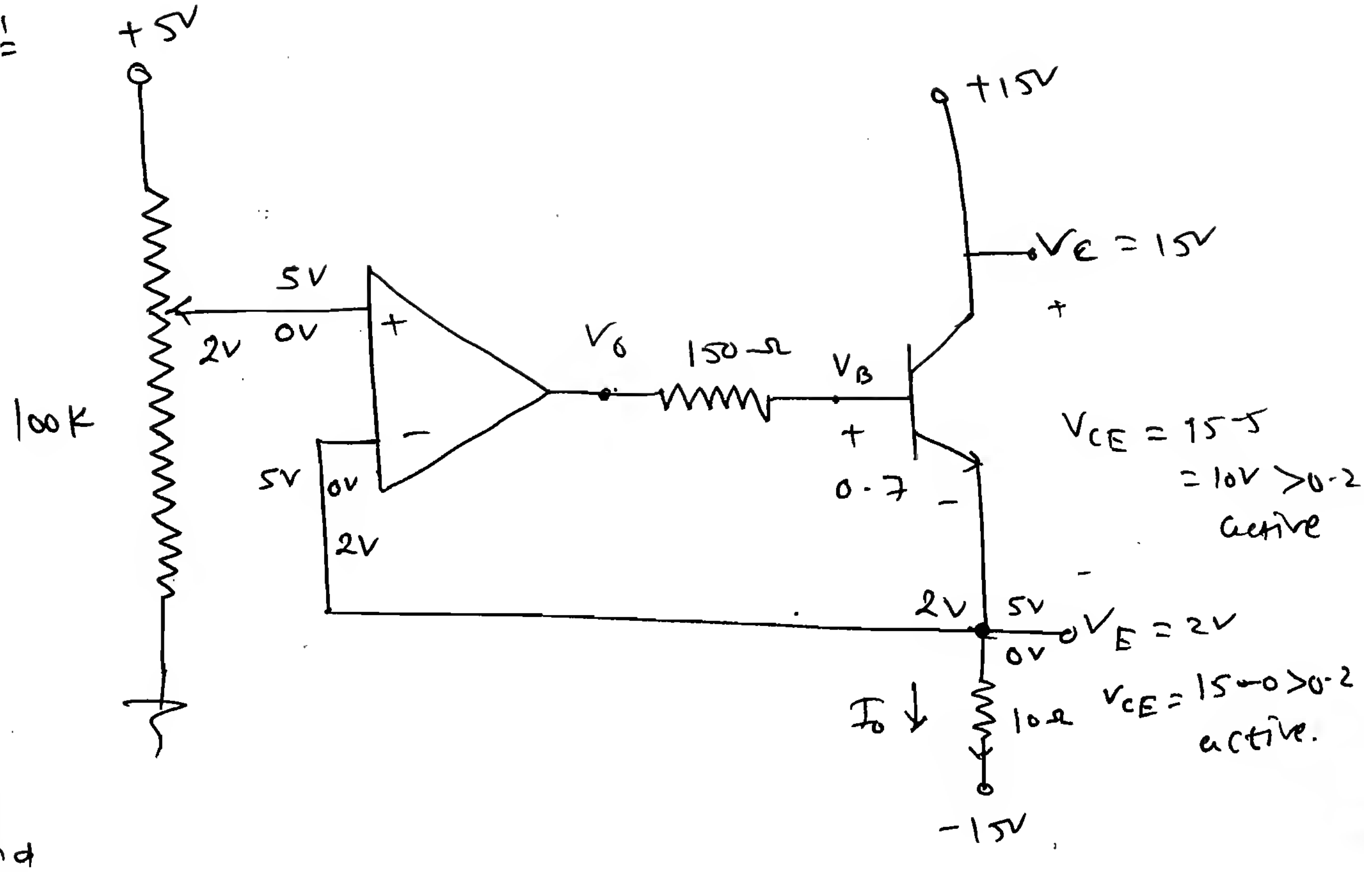
$\therefore R_L = V_C / I_C$

$\therefore R_{L\,min} = \frac{11.8}{1.5m}$

$\therefore \boxed{R_{L\,min} = 786\ \Omega}$

HM

Ex-1



Find

(a) Check the region of operation.

(b) If Vin = 2V then find V_o & I_o.

Ans: (a) Possible value of Vin is +5 & 0.

for Both the value transistor is active region as shown in ckt.

(b) Now, $V_{in} = 2V$

$\therefore V_E = 2V.$

$\therefore I_o = \dfrac{2 - (-15)}{10}$

$\therefore \boxed{I_o = 1.7\ A}$

$\therefore V_B - 0.7 = 2V$

$\therefore \boxed{V_B = 2.7V}$

$\therefore \dfrac{V_o - V_B}{150} = I_B$

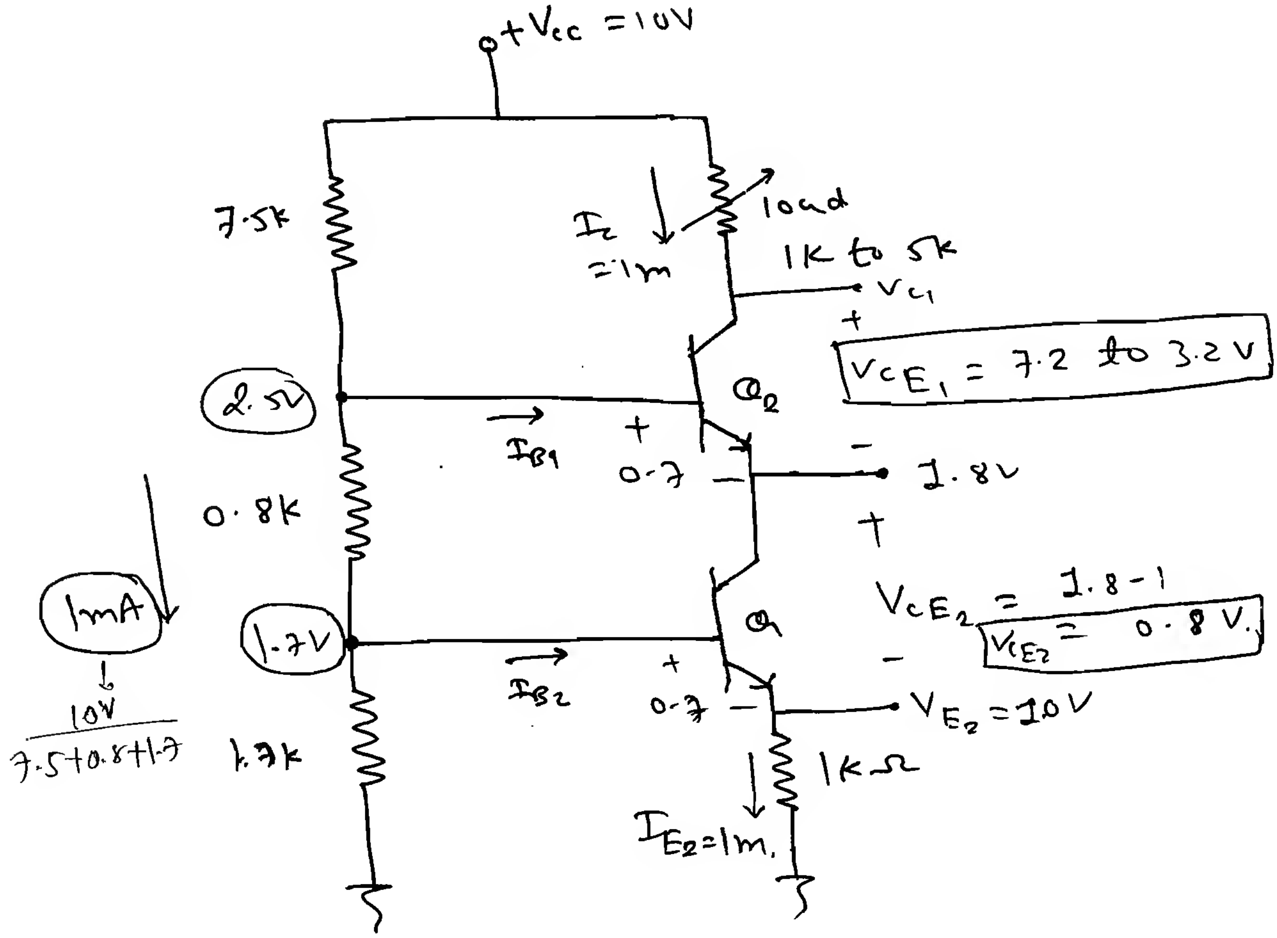
$\therefore \dfrac{V_o - V_B}{150} = \dfrac{I_E}{\beta + 1}$

$\therefore V_o - 2.7 = \dfrac{150 \times 1.7}{101}$

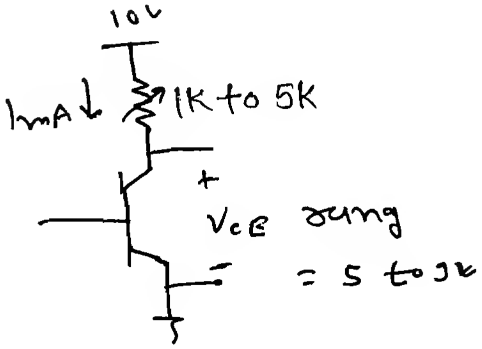
$\boxed{V_o = 5.224\ V}$

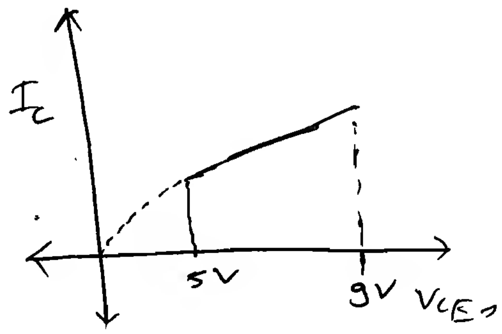
✪ Cascade Current Source for improved Stability on load Variations.

⇒



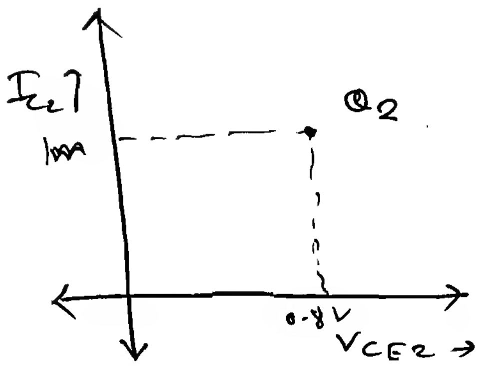
→





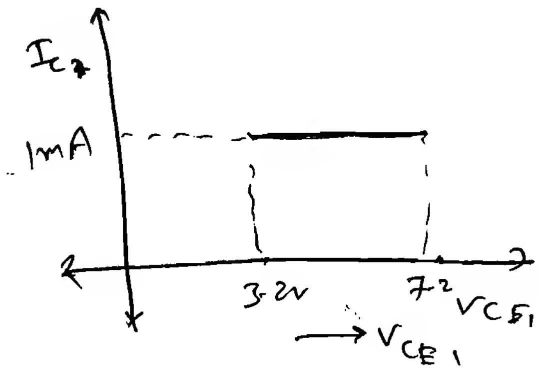
early effect.

→



[for Q_2]

→

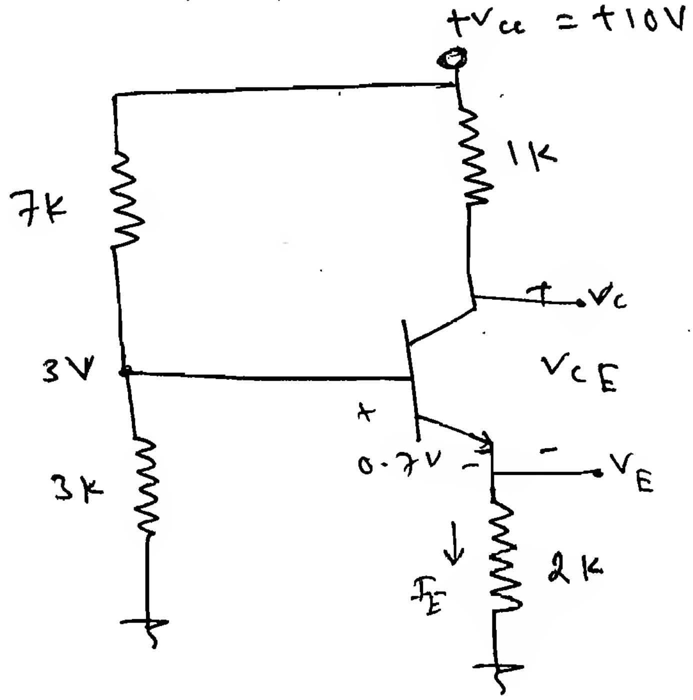


$R_o = \frac{1}{\text{Slope}} = 1/0 = \infty$

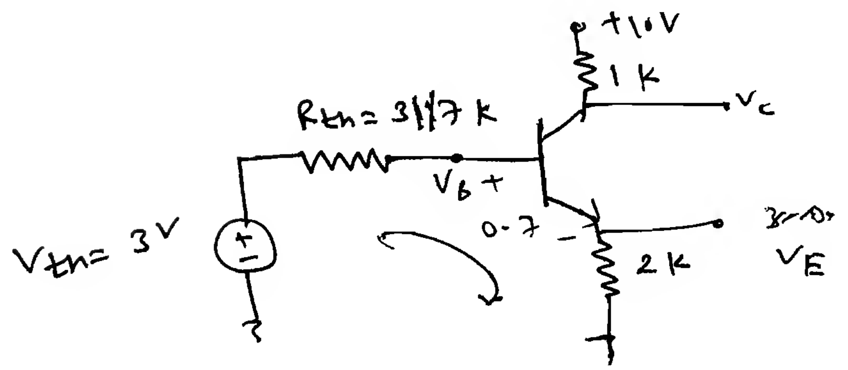
ideal current source

load	V_{CE_2}	V_{CE_1}	I_C
1K	0.8	7.2 V	1mA
2k	0.8	6.2 V	1mA
3K	0.8	5.2 V	1mA
4K	0.8	4.2 V	1mA
5K	0.8	3.2 V	1mA

Ex-1 Calculate all node voltages and Branch current if $\beta = 100$.



Ans:



$$\rightarrow \quad V_{th} - \frac{I_E}{\beta+1} R_{th} - V_{BE} - I_E R_E = 0$$

$$\therefore \quad I_E = \frac{V_{th} - V_{BE}}{R_E + \frac{R_{th}}{\beta+1}}$$

$$R_{th} = \frac{3\times 7}{10}$$

$$R_{th} = 2.1 \text{ k}\Omega$$

$$\therefore \quad I_E = \frac{3 - 0.7}{2 + \frac{2.1}{101}}$$

$$I_E = \frac{2.3}{2.02}$$

$$\therefore \boxed{I_E = 1.14\,mA.}$$

$$\therefore I_C = \frac{\beta}{\beta+1} \times I_E.$$

$$\therefore I_C = \frac{100}{101} \times 1.14\,mA$$

$$\therefore \boxed{I_C = 1.127\,mA}$$

$$\therefore V_C = V_{CC} - I_C R_C$$

$$\therefore V_C = 10 - (1.127 \times 1k).$$

$$\therefore \boxed{V_C = 8.87\,V} *$$

$$I_B = \frac{I_E}{\beta+1}.$$

$$\boxed{I_B = 11.29\,\mu A}$$

$$V_E = I_E R_E.$$

$$\therefore \boxed{V_E = 2.28\,V} *$$

$$\therefore \frac{V_{in} - V_B}{2.1k} = I_B.$$

$$\therefore 3 - V_B = 11.29 \times 10^{-6} \times 2.1k$$

$$\therefore 3 - V_B = 0.024.$$

$$\therefore \boxed{V_B = 2.976\,V} *$$

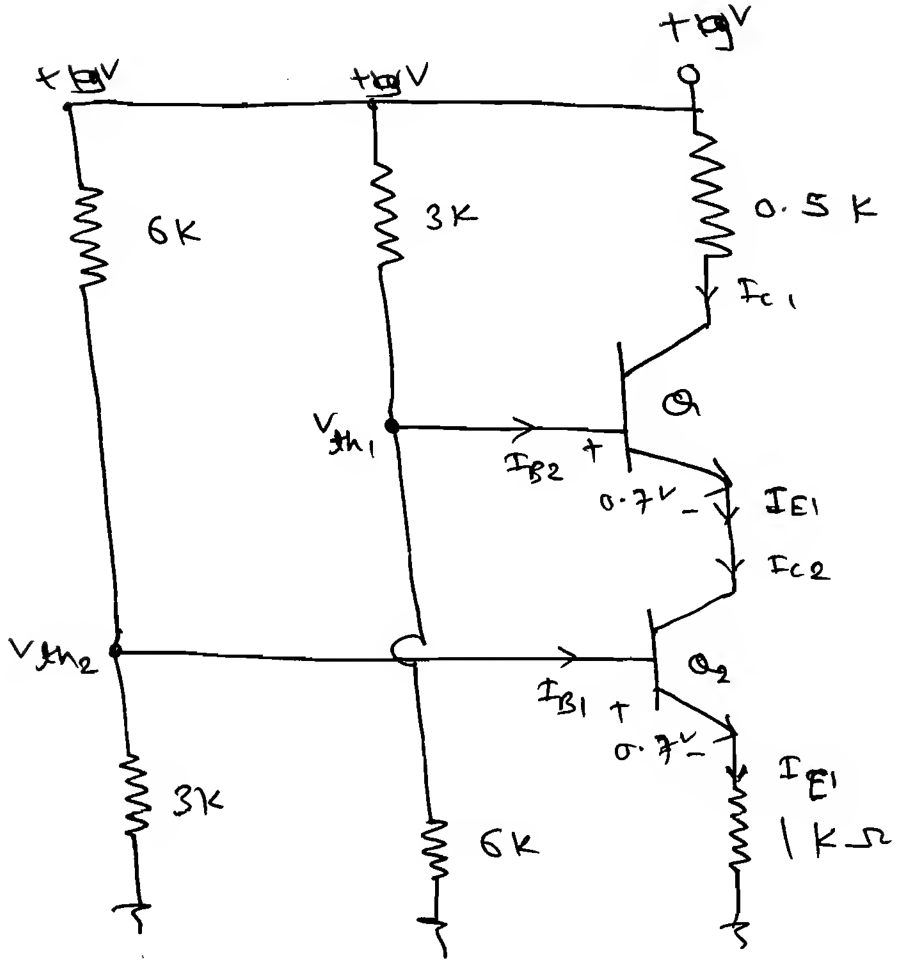
$$V_{CE} = V_C - V_E$$

$$\therefore V_{CE} = 8.87 - 2.28$$

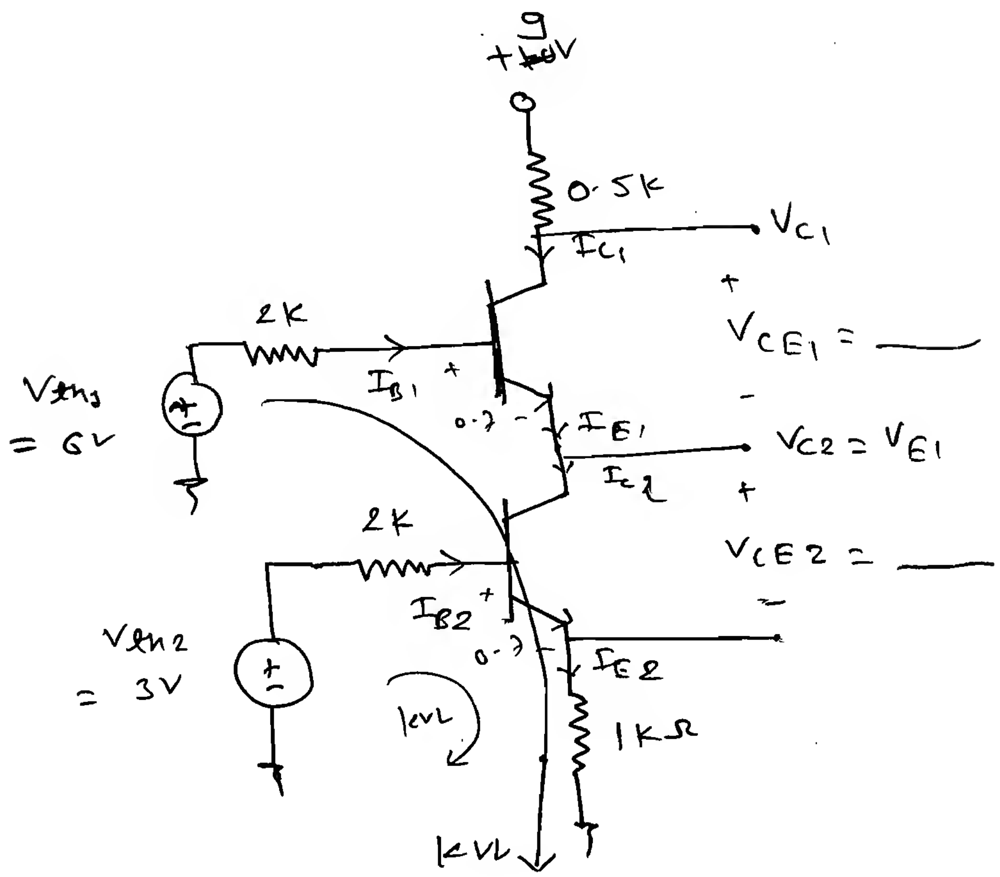
$$\therefore \boxed{V_{CE} = 6.59\,V} *$$

Ex-2 Calculate the all the Node Voltages and Branch currents.

⇒



Ans:



$$\therefore \quad I_{E2} = \frac{V_{th2} - V_{BE2}}{R_E + \frac{R_{th1}}{\beta+1}}$$

$$R_{th1} = \frac{3 \times 6}{9}$$

$$R_{th1} = 2\,K.$$

$$\therefore \quad I_{E2} = \frac{3 - 0.7}{1 + \frac{2}{101}}$$

$$V_{th1} = \frac{3}{8} \times 8$$

$$V_{th1} = 3\,V.$$

$$\therefore \quad \boxed{I_{E2} = 2.255\ mA}$$

$$\therefore \quad I_{C2} = \frac{\beta}{\beta+1} \times I_{E2}.$$

$$\therefore \quad I_{C2} = \frac{100}{101} \times 2.255$$

$$\therefore \quad \boxed{I_{C2} = 2.23\ mA}$$

$$\therefore \quad I_{B2} = \frac{I_{E2}}{\beta+1}.$$

$$\therefore \quad \boxed{I_{B2} = 22.33\ \mu A.}$$

$$\therefore \quad I_{E1} = I_{C2}.$$

$$\therefore \quad \boxed{I_{E1} = 2.23\ mA.}$$

$$\therefore \quad I_{C1} = \frac{\beta}{\beta+1} \times I_{E1}$$

$$\therefore \quad I_{C1} = \frac{100}{101} \times 2.23$$

$$\therefore \quad \boxed{I_{C1} = 2.21\ mA.}$$

$$\therefore \quad I_{B1} = \frac{I_{E1}}{\beta+1} \quad \therefore \quad \boxed{I_{B1} = 22.08\ \mu A}$$

$\therefore V_{E2} = I_{E2} \times R_{E2}$

$\therefore V_{E2} = 2.255 \times 1$

$\therefore \boxed{V_{E2} = 2.255\,V}$ *

$\therefore V_{C1} = 9 - I_{C1} R_{C1}$

$\therefore V_{C1} = 9 - (2.21 \times 0.5).$

$\therefore \boxed{V_{C1} = 7.895\,V}$ *

$\therefore V_{th1} - I_{B1} R_{th1} - 0.7 - V_{CE2} - I_{E2} R_{E2} = 0.$

$\therefore V_{CE2} = 6 - (0.02208 \times 2) - 0.7 - (2.255 \times 1)$

$\therefore \boxed{V_{CE2} = 3\,V}$ ☆

$\therefore V_{CE2} = V_{C2} - V_{E2}$

$\therefore V_{C2} = 3 + 2.255$

$\therefore \boxed{V_{C2} = 5.255\,V}$ *

$\therefore V_{E1} = V_{C2}$

$\therefore \boxed{V_{E1} = 5.255\,V}$ *

$\therefore V_{CE1} = V_{C1} - V_{E1}$

$\therefore V_{CE1} = 7.895 - 5.255$

$\therefore \boxed{V_{CE1} = 2.64\,V.}$ ☆

V_{B1} $\frac{V_{th1} - V_{B1}}{R_{th1}} = I_{B1}$

$\therefore V_{B1} = V_{th1} - I_{B1} R_{th1}$

$\therefore V_{B1} = 6 - (0.02208 \times 2).$

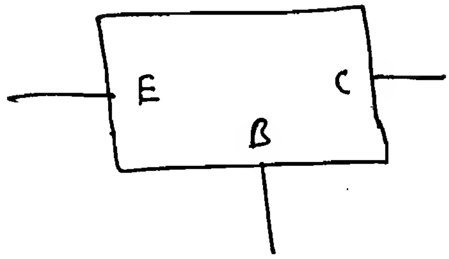
$\boxed{V_{B1} = 5.9558\,V}$ *

$V_{B2} = V_{th2} - I_{B2} R_{th2}.$

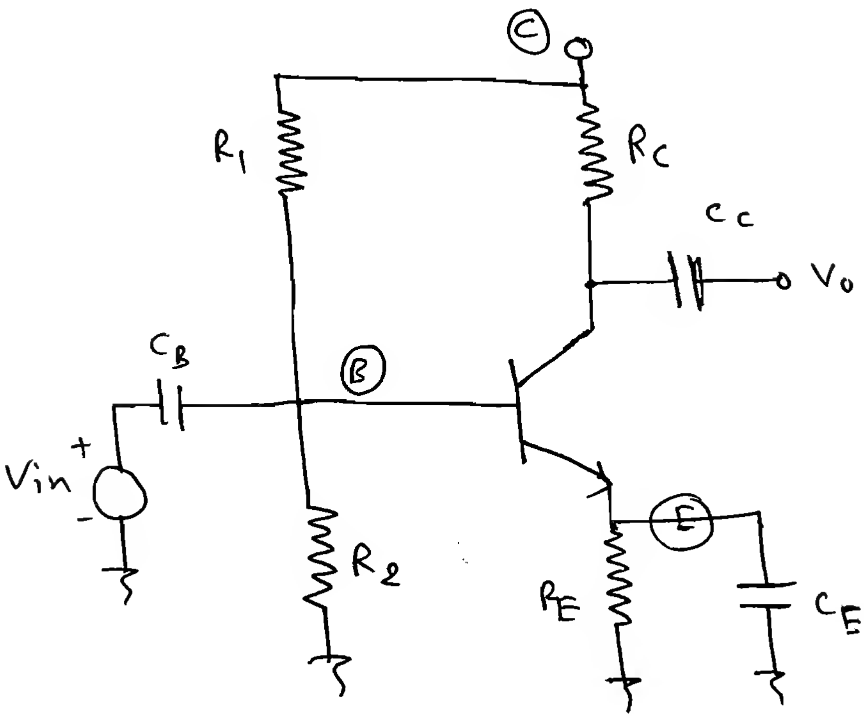
$\therefore \boxed{V_{B2} = 2.955\,V}$ *

☆ Configuration of BJT :

1) Common Emitter
2) Common Base
3) Common Collector



① Common Emitter:



$Z_{in} = 1\ k\Omega$

$Z_o = 50\ k\Omega$

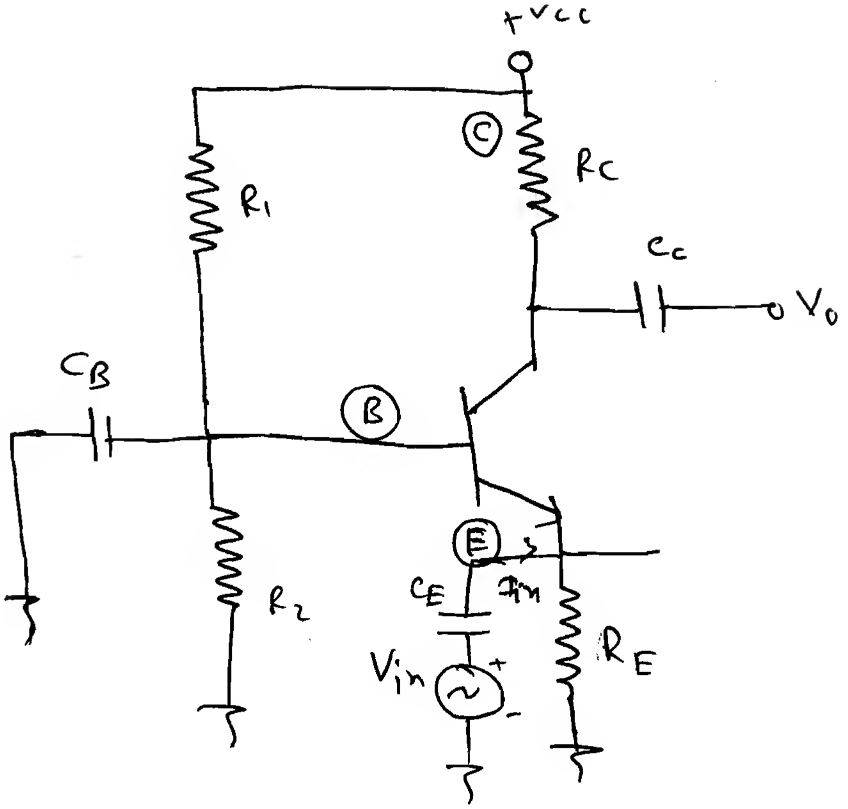
$A_V = -200$

$A_I = -100$

$A_P = A_V A_I$

Very high power gain.

② Common Base:



$$Z_{in} = \frac{V_{in}}{R_{in}} = 30\,\Omega \Rightarrow CC$$

$\therefore$ $Z_o = 1\,M\Omega \Rightarrow CS$

$\therefore$ CB $\Rightarrow$ CCCS.

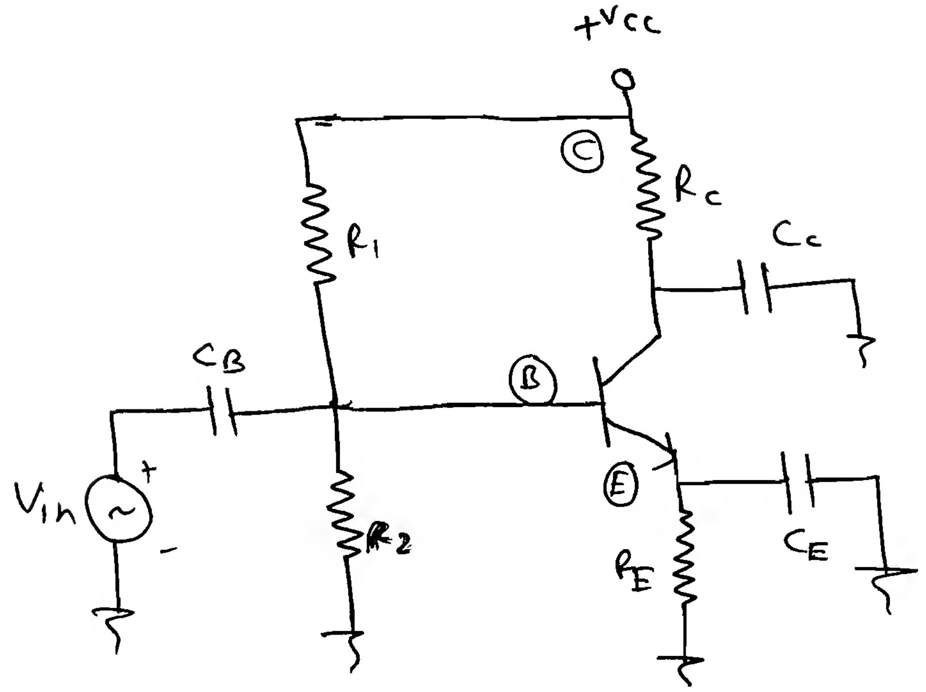
$\rightarrow$ $A_I = 1 \Rightarrow$ Current Buffer

$\therefore$ $A_V = 600$

$\therefore$ $A_P = A_V \cdot A_I$

$A_P = 600.$

(3) Common Collector:



$Z_{in} = 9\,M\Omega$ (VC).

$Z_o = 8\,\Omega$ (VS).

$\boxed{CC \rightarrow VCVS}$

$A_V = 1 \longrightarrow$ Voltage Buffer

$A_I = 100.$

$\therefore A_P = A_V \cdot A_I$

$\therefore \boxed{A_P \cong A_I}$

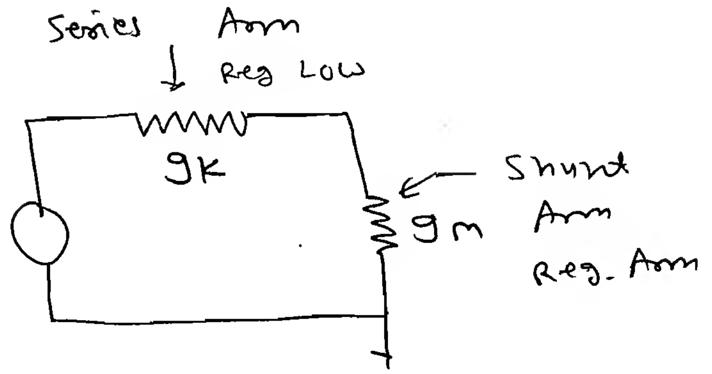
* Input impedence is found for Impedence matching.

* Output Resistance is found for Maximum power transfer.

If O/P Resistance = Load Resistance

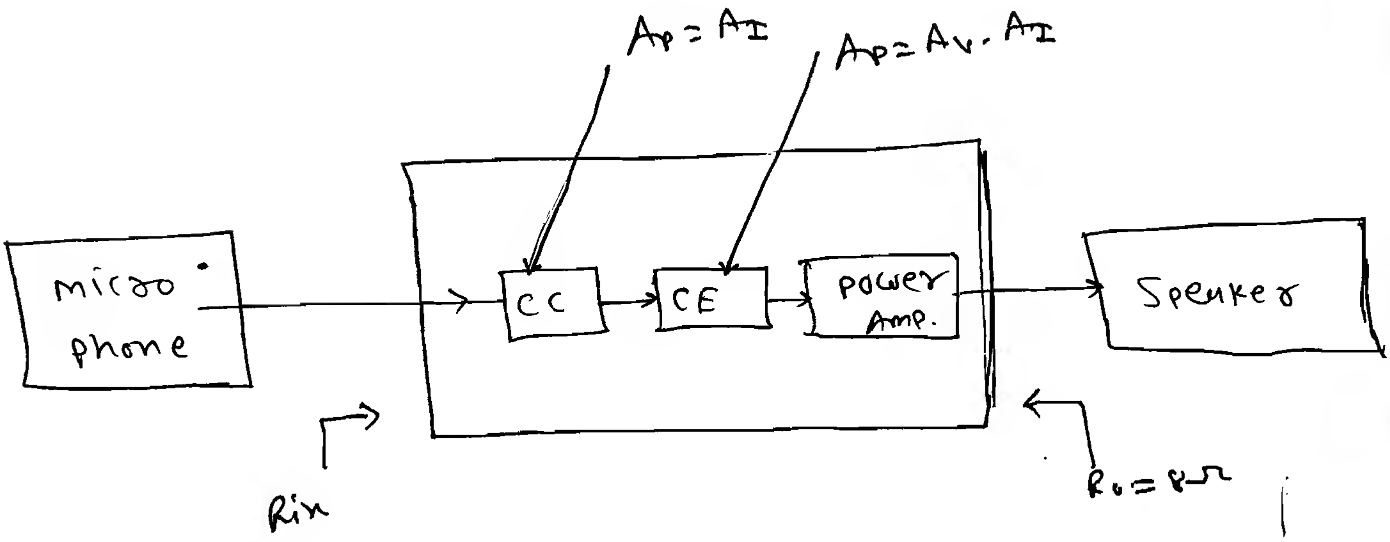
$\Downarrow$

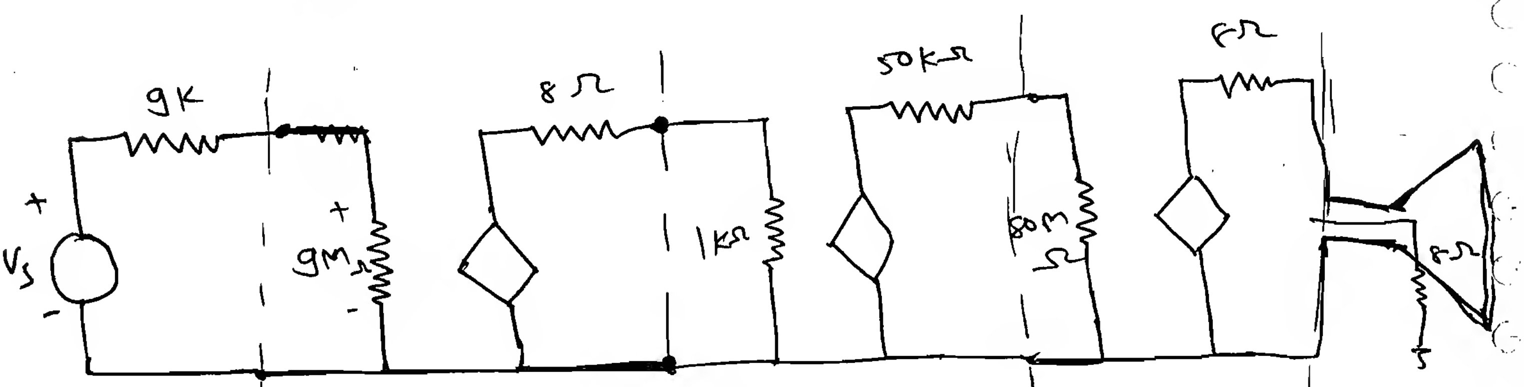
Maximum power can be transfered.



$\Rightarrow$ Good Ampⁿ.

*

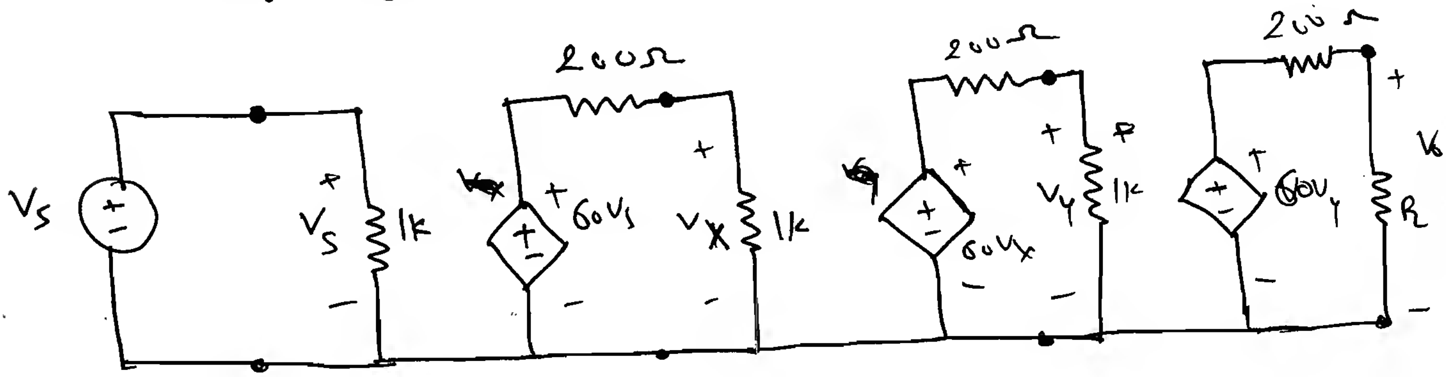




Microphone (Source)	$\boxed{CC}$	$\boxed{CE}$	$\boxed{\text{Power Amp}}$	(Speaker) (Load)
	• Rin = high	Rin = Moderate		
	Ro = Low	Ro = "		
	$\boxed{VCVC}$	Ap = Av . AI		
	Ap = AI			

$\longleftarrow$ Amplifier $\longrightarrow$

Ex:(1) GATE Imp An Amp has an input Resistor of $1\,k\Omega$, o/p Resistor = $200\,\Omega$. If and open loop voltage gain $A_o = 60$. If 3 similar stages cascaded with a load Resistor $R_L = 2.2K$. Find the over all voltage gain.



$$\therefore\ A_v = \frac{V_o}{V_s} = \frac{V_o}{V_y} \times \frac{V_y}{V_x} \times \frac{V_x}{V_s}$$

$$\therefore\ V_x = \frac{60 V_s \times 1K}{200 + 1K}$$

$$\therefore\ \boxed{V_x = 50.}\ V_s$$

$$\therefore\ \boxed{\frac{V_x}{V_s} = 50.}$$

$$\therefore\ V_y = \frac{60 V_x \times 1000}{1200}$$

$$\therefore\ \boxed{\frac{V_y}{V_x} = 50}$$

$$\therefore\ V_o = \frac{60 V_y \times 2200}{2400}$$

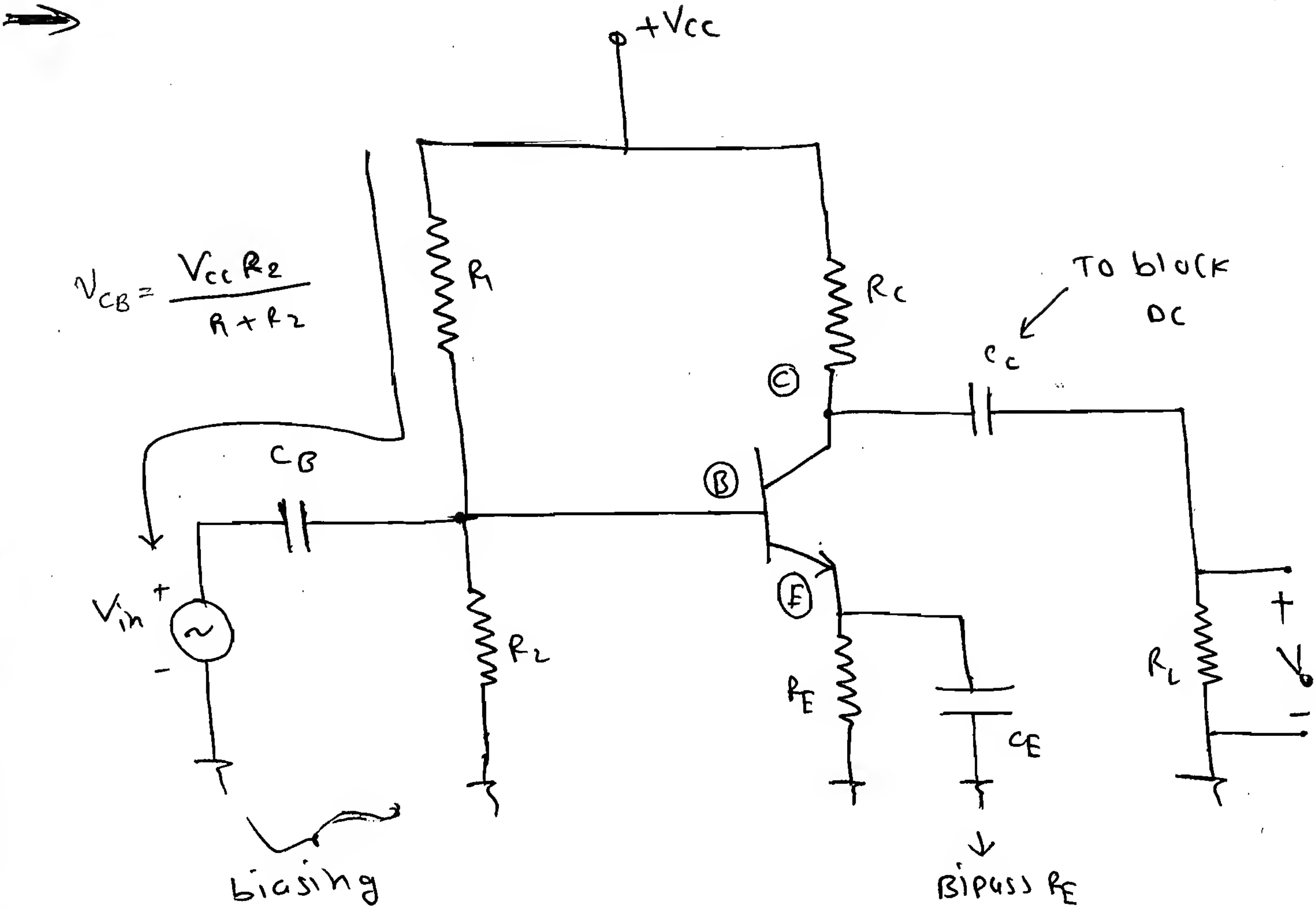
$$\boxed{\frac{V_o}{V_y} = 55.}$$

$$\therefore\ A_v = 55 \times 50 \times 50$$

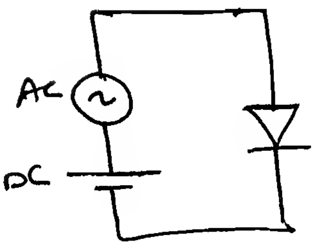
$$\boxed{A_v = 1.375 \times 10^5.}$$

★ Small Signal Analysis of BJT :-

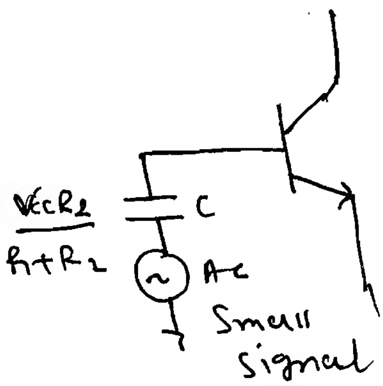
→



→



Non-linear ⇒ linear



Non linear ⇒ linear.

→ If <u>load</u> connected <u>to Vcc</u> it is called <u>floating load</u> and it is <u>R_C coupled ckt.</u>

→ If <u>load</u> is connected to <u>ground then</u> it is called <u>grounded load</u> and called <u>Direct coupled</u> ckt.

* Purpose of each capacitor:

→ ① C_B → for DC biasing.

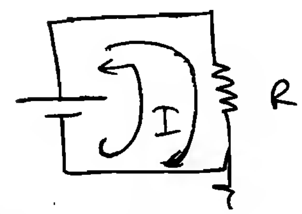
② C_E → To block DC and allow AC in V_o.

③ C_E $\boxed{C_E}$ → Bypass C_E.

→ (i) C_E behaves as open circuit for DC signal and it allows R_E to play its Role in establishing β independent DC collector current. ($I_{C_{DC}}$).

(ii) C_E behaves as short circuit for AC signal eliminating the Gain Reducing emitter Resistor.

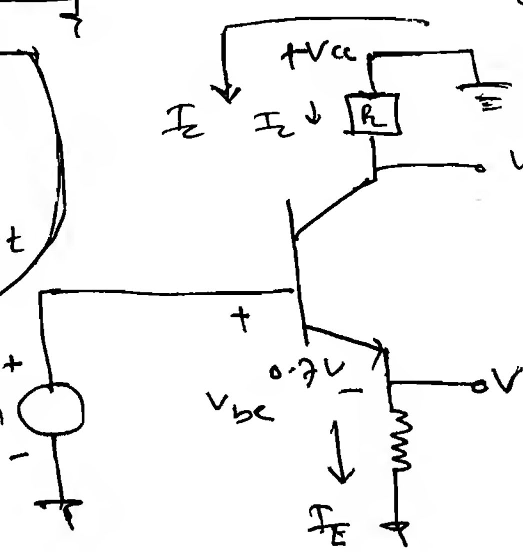
*



→ Going to ground $V = IR$

→ Coming from gnd. $V = -IR$.

CE Amp. BJT gives 180° phase shift as we get '-' in V_o.



$$V_{in} = V_{be} + I_E R_E$$

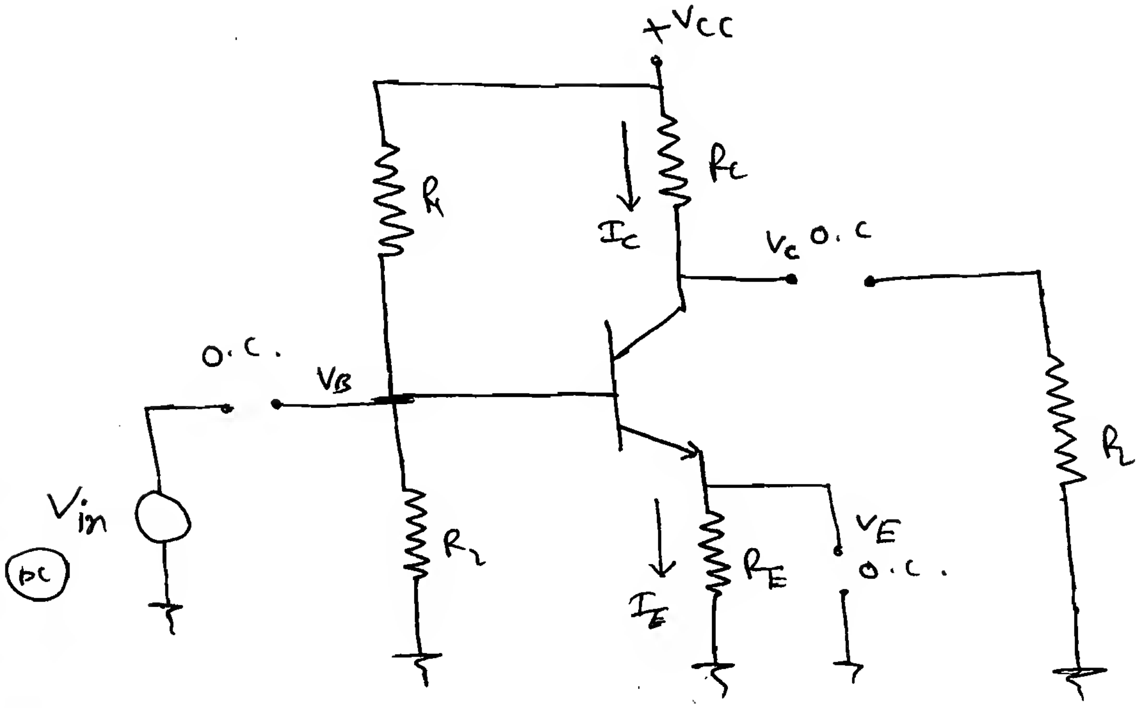
$$\therefore A_v = \frac{V_o}{V_{in}}$$

$$\therefore \boxed{A_v = \frac{-I_c R_c}{V_{be} + I_E R_E}}$$

① DC picture:

→ open circuit the all capacitor.

After that it is self bias.



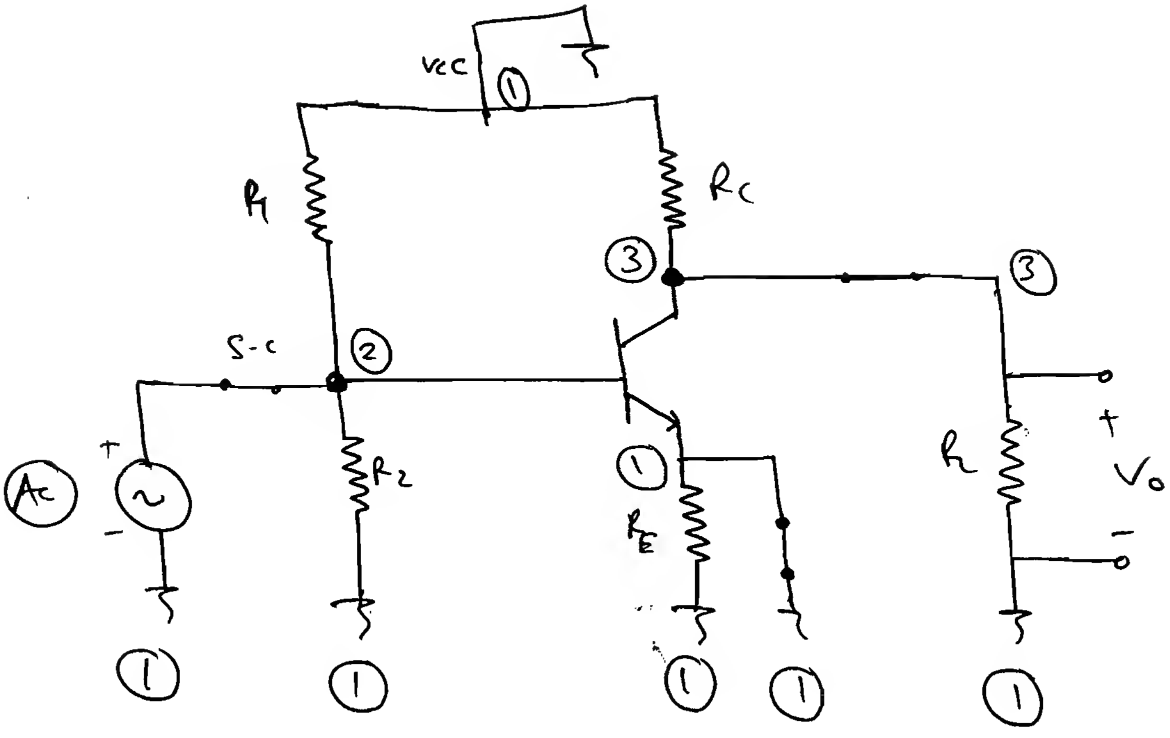
$$\therefore V_{e_{DC}} = V_{cc} - I_{c_{DC}} R_c$$

$$\therefore V_{e_{DC}} = V_{cc} - \left[\frac{\frac{V_{cc} R_2}{R_1 + R_2} - V_{BE}}{R_E + \frac{R_1 \| R_2}{\beta + 1}} \right] \cdot R_c$$

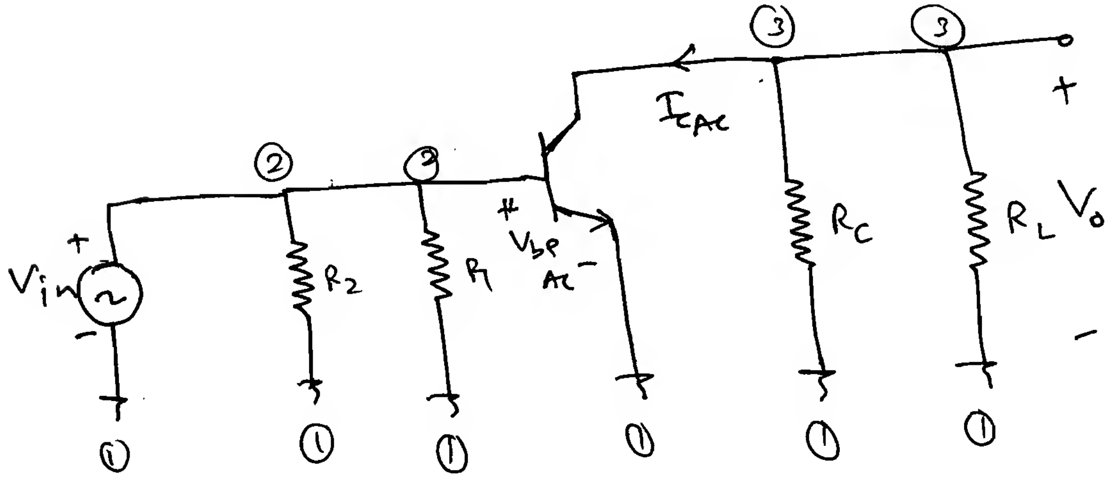
$$\rightarrow I_{c_{DC}} = I_E = \frac{\frac{V_{cc} R_2}{R_1 + R_2} - V_{BE}}{R_E + \frac{R_1 \| R_2}{\beta + 1}}$$

(2) Ac Picture:

→ Short ckts all the capacitor and DC supply i.e. V_{cc}.



⇓



$$\therefore \quad V_o = -I_{C_{Ac}} (R_C \| R_L).$$

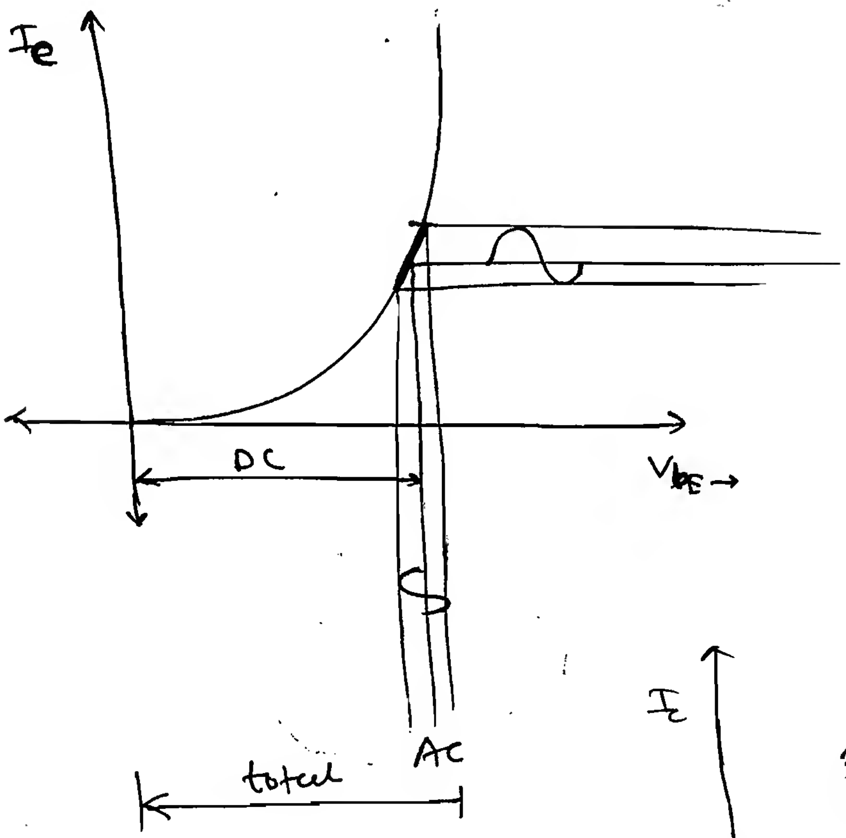
$$\therefore \quad V_{in} = V_{be\,(Ac)}.$$

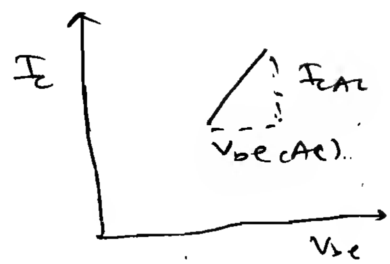
$$A_V = \frac{V_o}{V_{in}}$$

$$A_V = \frac{-I_{c(AC)}}{V_{be(AC)}} [R_C \parallel R_L].$$

$$\therefore \boxed{A_V = -g_m [R_C \parallel R_L].}$$

→ $$I_c = I_s \cdot e^{V_{be}/V_t}$$





$$g_m = \frac{dI_c}{dV_{be}}$$

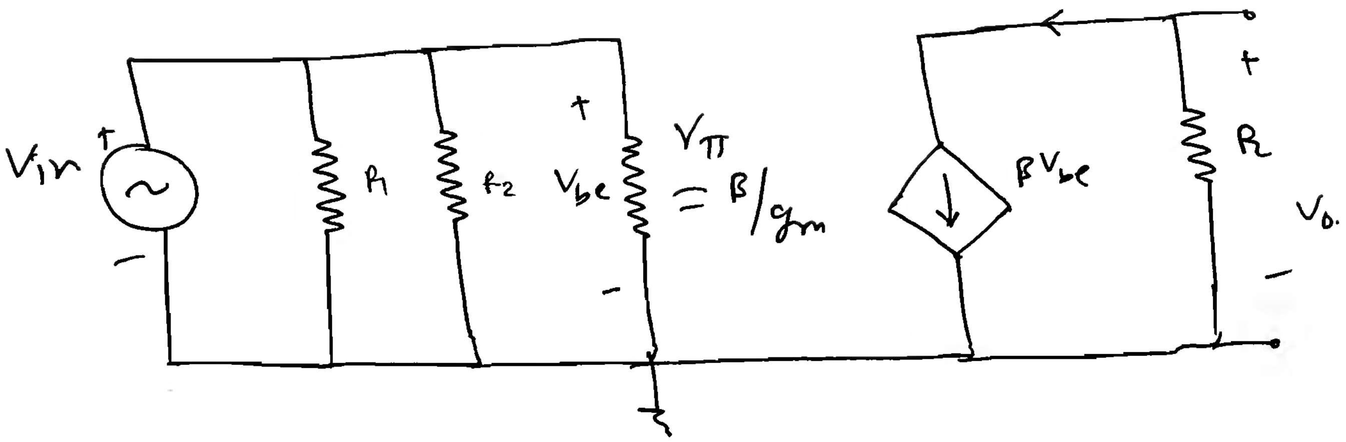
$$= I_s \cdot e^{V_{be_{DC}}/V_t} \cdot \frac{1}{V_t}$$

where

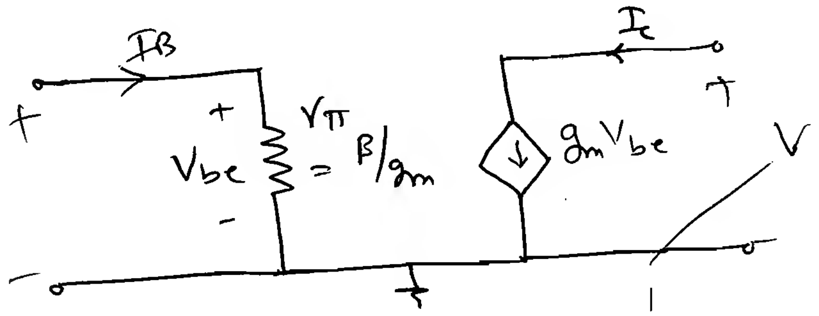
$$g_m = \frac{I_{cDC}}{V_t}.$$

$$\therefore g_m = \frac{I_{c,DC}}{V_t}$$

*



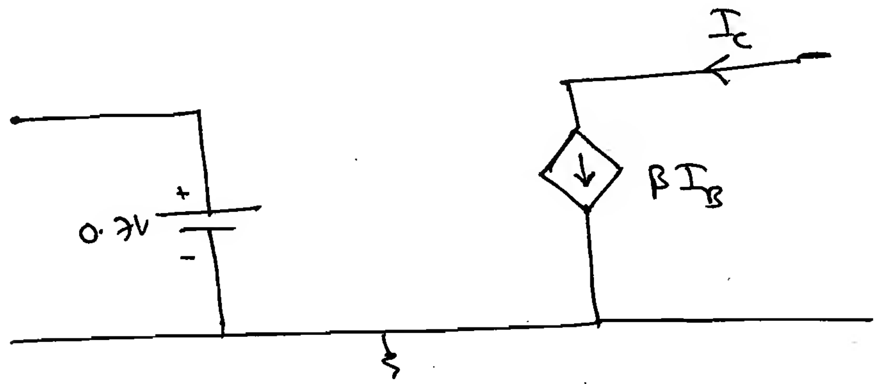
* AC model:



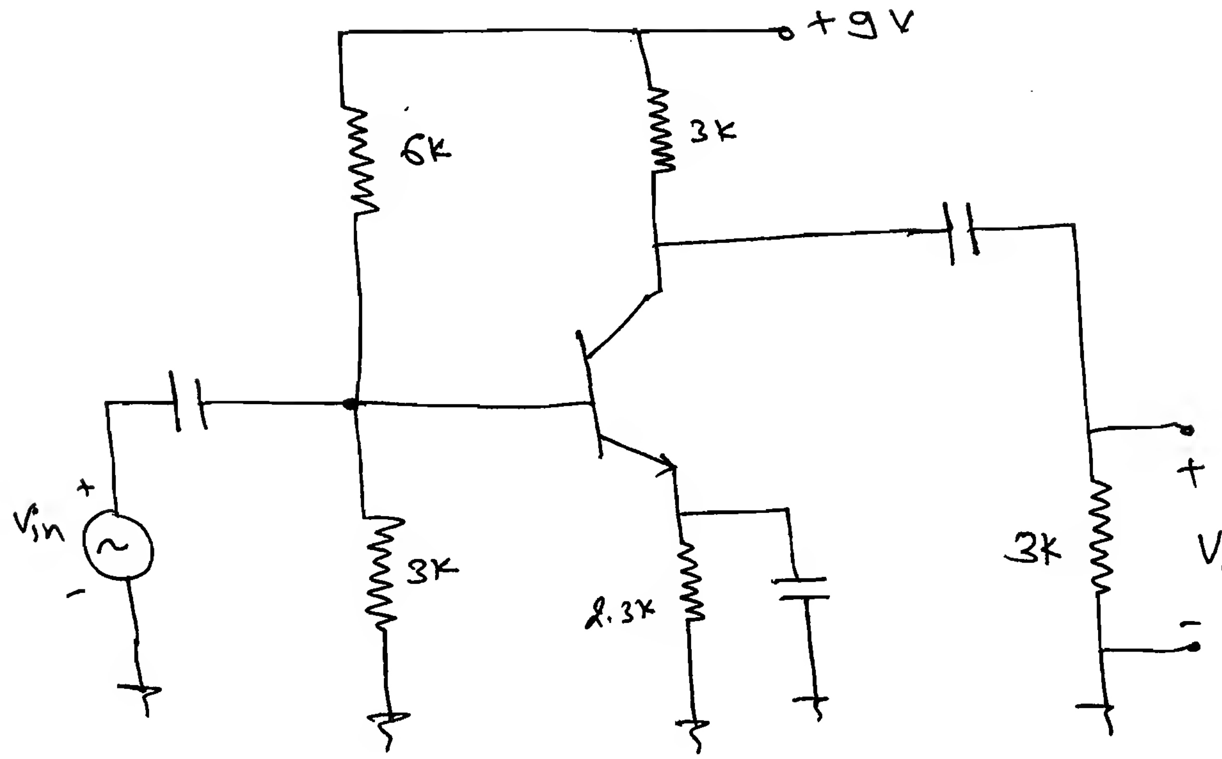
$g_m = \frac{I_{C\,DC}}{V_t}$.

r_π = Base to emitter resistance.

* DC model:



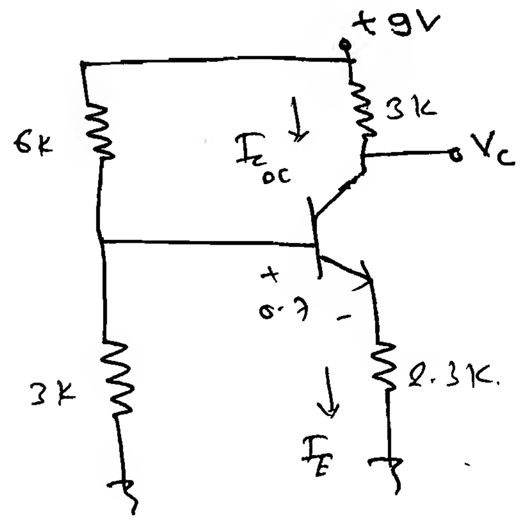
Ex-1 Find the voltage gain V_o/V_{in} if β is very large.



Ans:

① DC picture:

o.c. the capacitor



$\therefore \quad V_{th_1} = 3V, \quad R_{th} = 2k.$

$$\therefore \quad I_E = \frac{V_{th} - V_{BE}}{R_E + \frac{R_{th}}{\beta+1}}$$

$$\therefore \quad I_E = \frac{3 - 0.7}{2.3 + 0} \quad (\because \beta \gg \text{very large})$$

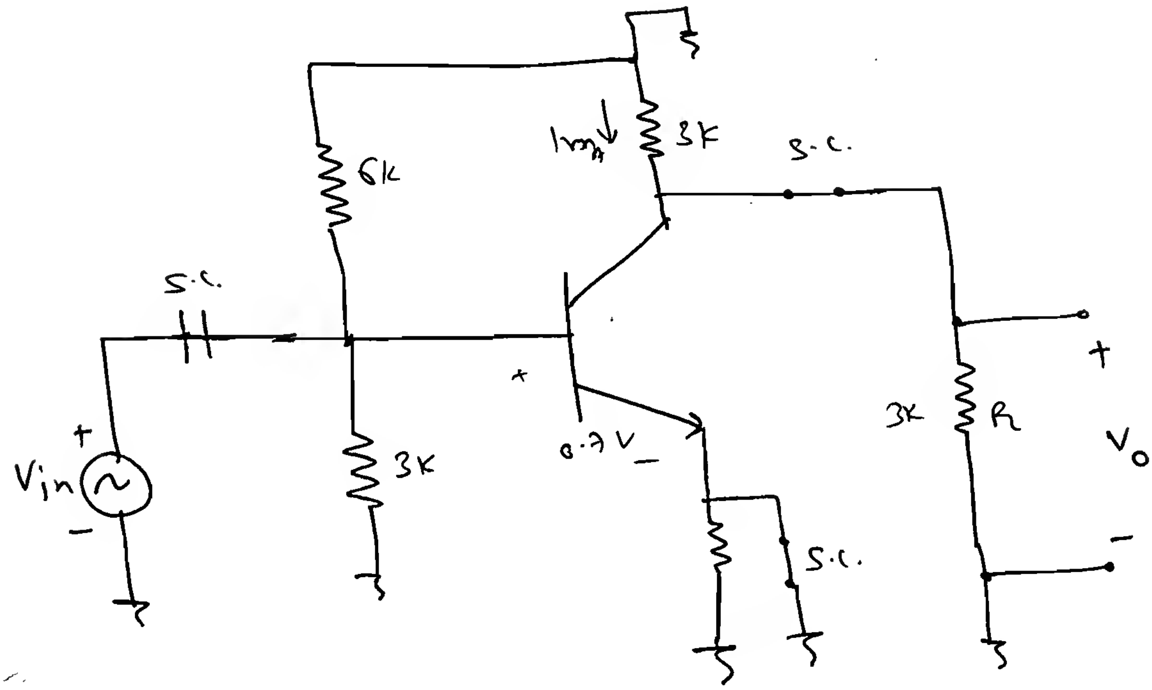
$\therefore \boxed{I_E = 1mA.}$

$\therefore \quad I_{C_{DC}} = \frac{\beta}{\beta+1} \cdot I_E = I_E \quad (\because \beta \text{ is very large}).$

$\therefore \boxed{I_{C_{DC}} = 1mA}$

→ (2) AC picture

s.c. Capacitors and DC sources.



|||

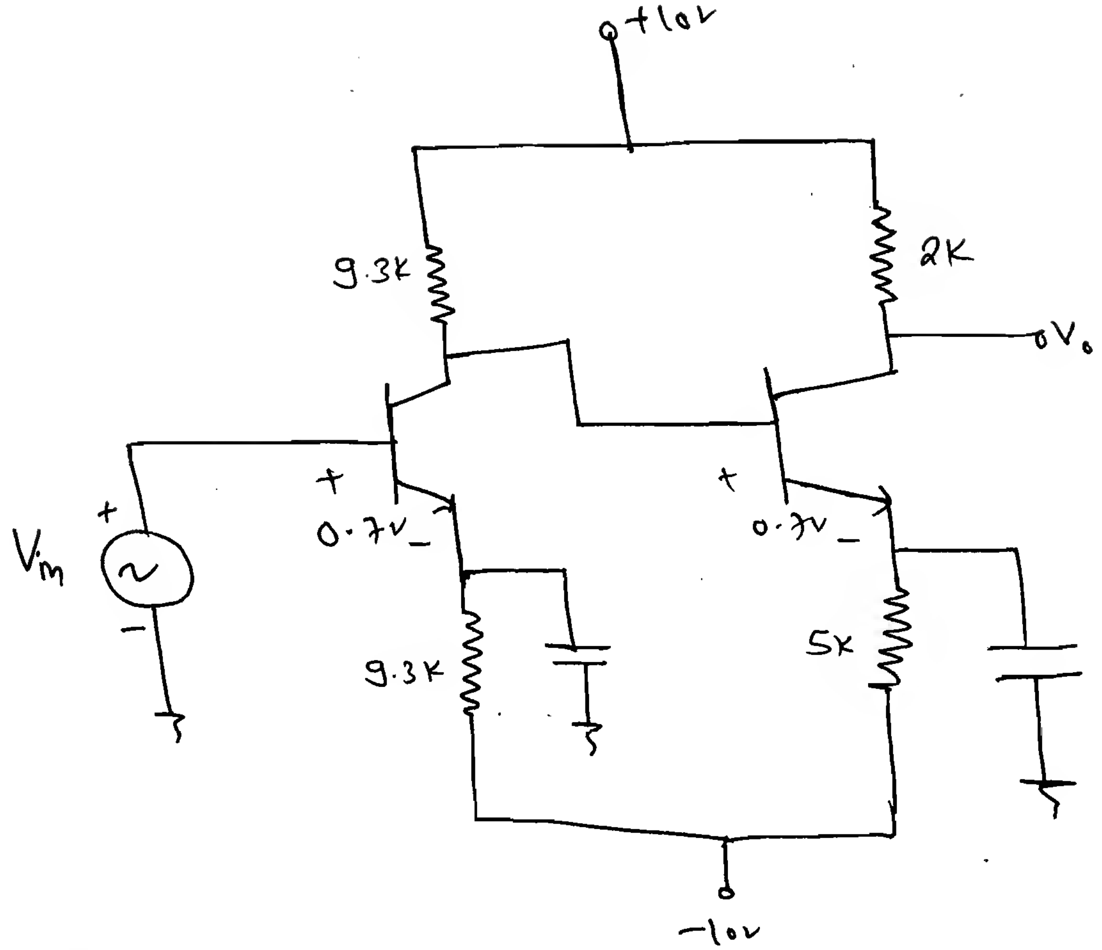
$\therefore \frac{V_o}{V_{in}} = -g_m (R_C \| R_L).$ $\qquad g_m = \frac{I_{C_{DC}}}{V_t}.$

$g_m = \frac{1m}{25m} = 0.04$

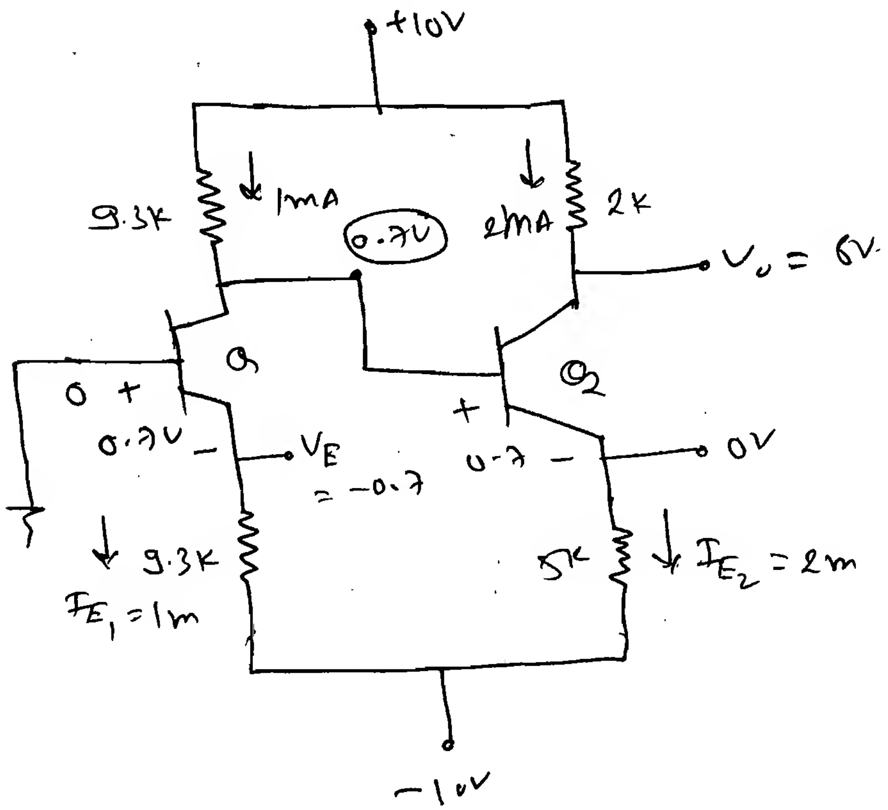
$\therefore \frac{V_o}{V_{in}} = -0.04 [1.5].k$

$\Rightarrow \frac{V_o}{V_{in}} = \frac{1}{-25} \times 1500 = 60 \qquad \therefore \boxed{\frac{V_o}{V_{in}} = -60}$

Ex-2 Find V_o:



Ans: ① Dc picture.



$\therefore$ $V_{E_1} = 0 - 0.7$

$V_{E_1} = -0.7V$

$$\rightarrow \quad I_{E_1} = \frac{-0.7-(-10)}{9.3k}$$

$$= \frac{9.3}{9.3k}$$

$\therefore \ I_{E_1} = 1m$

$\therefore \ \boxed{I_{C_1 \, DC} = 1m.}$

$\therefore \ V_{C_1} = 10 - (9.3 \times 1).$

$\boxed{V_{C1} = 0.7V}$

$\therefore \ V_{E2} = 0.7 - 0.7 = 0V.$

$\therefore \ I_{E2} = \dfrac{V_{E2} - (-10)}{5k}$

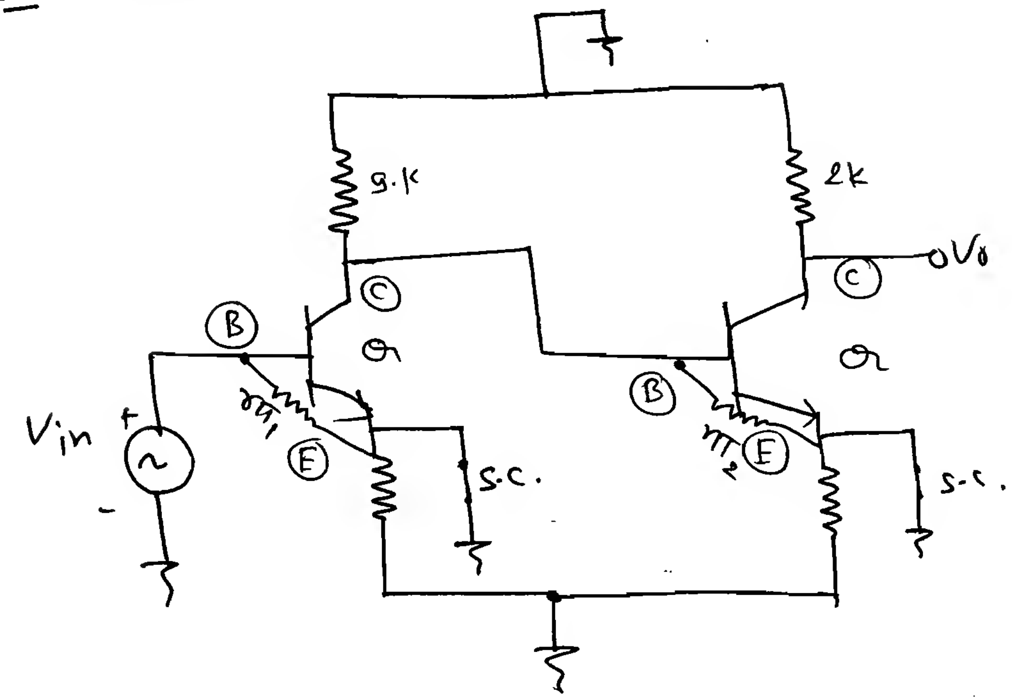
$I_{E2} = 2mA$

$\therefore \ \boxed{I_{C2 \, DC} = 2mA.}$

$\therefore \ V_o = 10 - (2(2))$

$\boxed{V_o = 6V}$

② AC picture:



Q1 | Q2

$$g_{m_1} = \frac{I_{C_{DC1}}}{V_t}$$

$$g_{m_1} = \frac{1m}{25m}$$

$$\boxed{g_{m_1} = \frac{1}{25}}$$

$$r_{\pi_1} = \beta / g_{m_1}$$

$$r_{\pi} = \frac{100}{1/25}$$

$$\boxed{r_{\pi} = 2.5k\Omega}$$

$$g_{m_2} = \frac{I_{C_{DC2}}}{V_t}$$

$$= \frac{2m}{25m}$$

$$\therefore \boxed{g_{m_2} = \frac{2}{25}}.$$

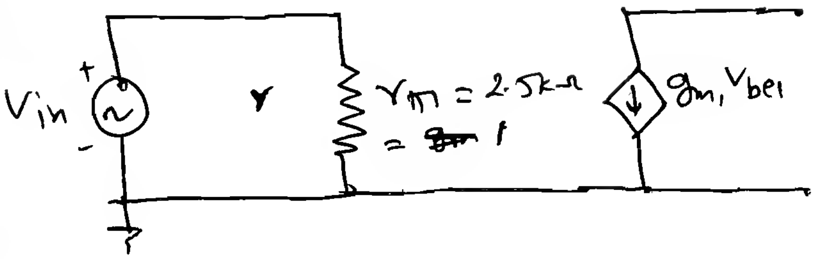
$$r_{\pi 2} = \beta / g_{m_2}$$

$$\therefore r_{\pi 2} = 100/2/25$$

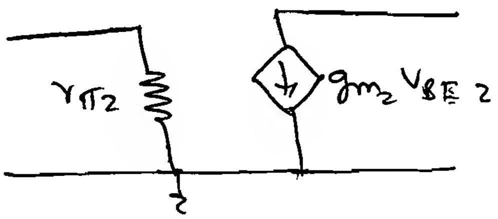
$$\therefore \boxed{r_{\pi 2} = 1.25k\Omega}$$

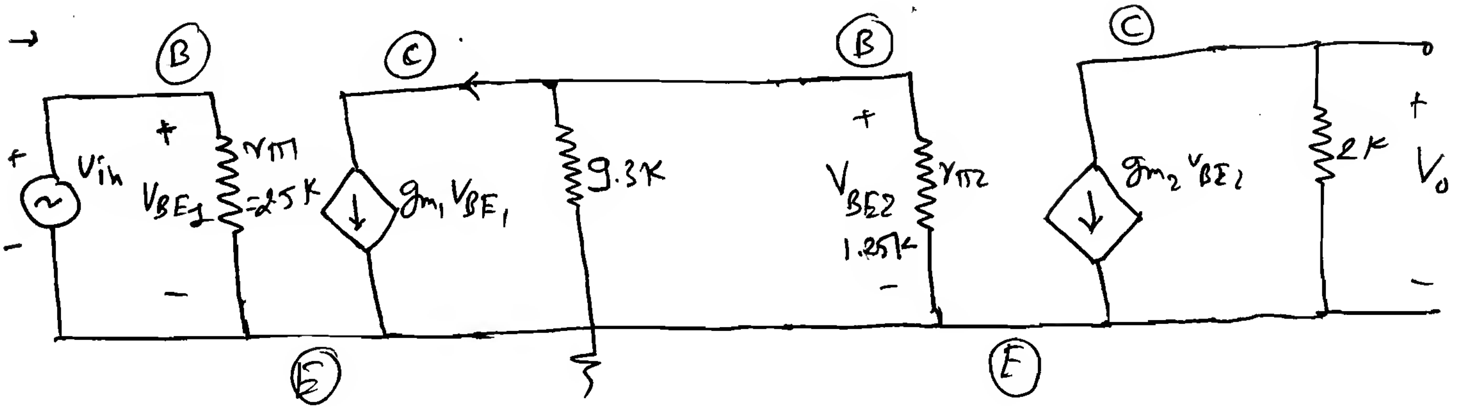
Now,

Q1



Q2





$$\therefore \frac{V_o}{V_{in}} = \frac{V_o}{V_{BE2}} \times \frac{V_{BE2}}{V_{BE1}}.$$

$$\therefore V_{BE_2} = -g_{m1} \cdot V_{BE1} \cdot (1.25k \,||\, 9.3k).$$

$$\therefore \frac{V_{BE_2}}{V_{BE_1}} = -g_{m1} (1.25k \,||\, 9.3k).$$

$$\therefore V_o = -g_{m2} V_{BE2} \; (2k).$$

$$\therefore \frac{V_o}{V_{in}} = -g_{m2} (2k) \times -g_{m1} (1.25k \,||\, 9.3k).$$

$$= \frac{2}{25} \times \frac{1}{25} \times (2000) ($$

$$\therefore \frac{V_o}{V_{in}} = A_v = 7052.$$

Now, $V_o = 7052 \times V_{in}$

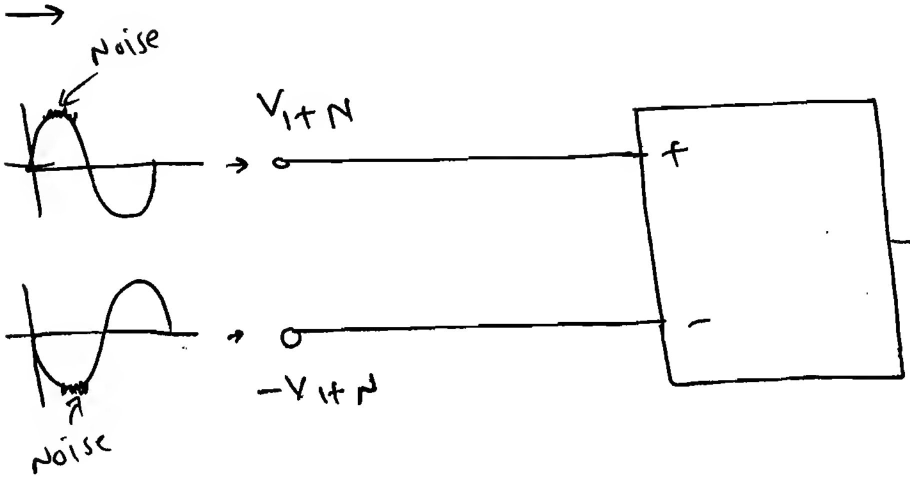
But $V_{in} = V_{BE1} = 0.7$

$$\therefore V_o = 7052 \times V_{BE1} = 7052 \times 0.7$$

$$\therefore \boxed{V_o = 4936.5\,V}$$

☆ Differential Amplifier:

→

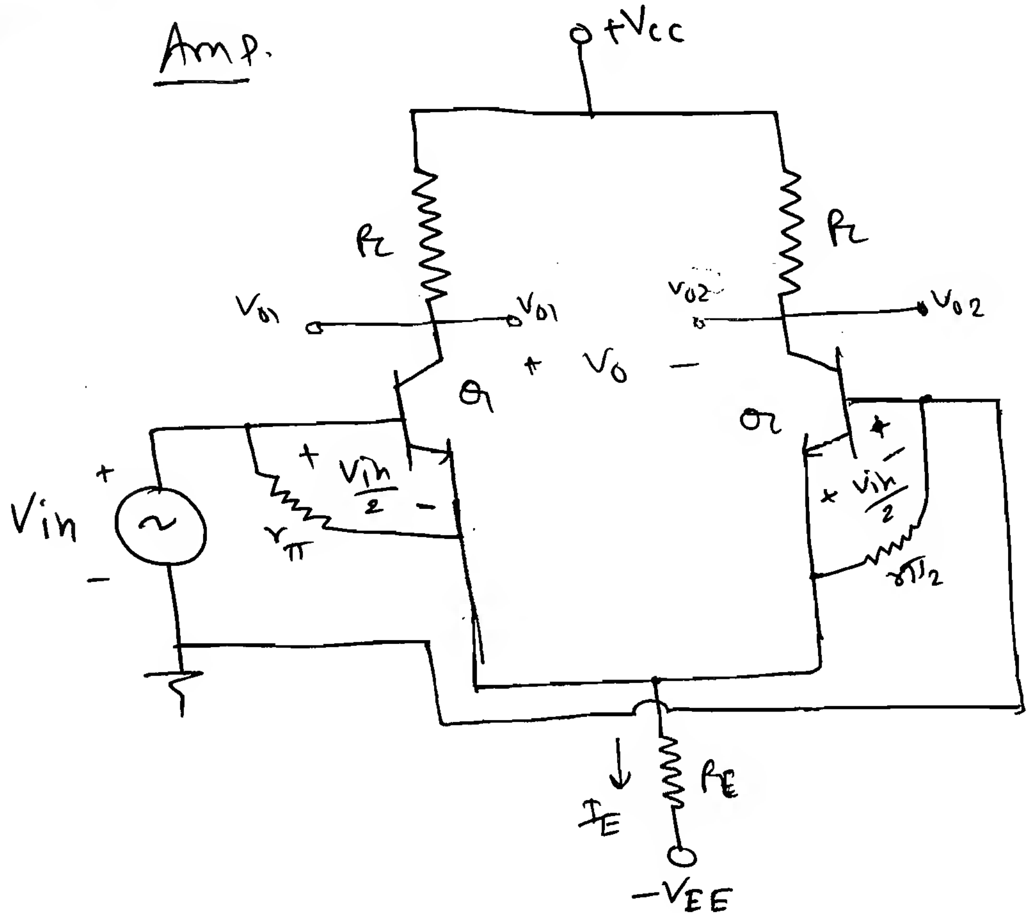


$V_0 = V_1+N - (-V_1+N)$
$= 2V_1$

So, common noise gets cancelled out at output by taking differential measurement.

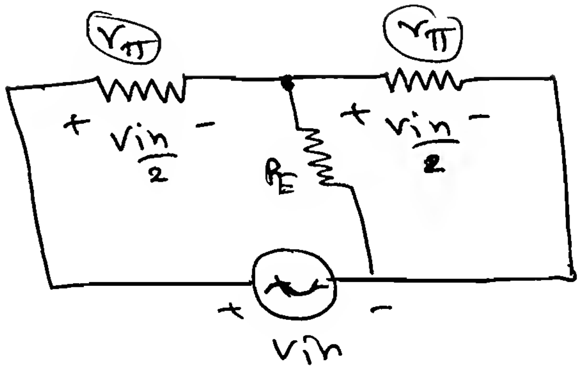
Direct Coupled Amp.

⇒



→ For DC analysis we will get $I_{C_1 DC}$ & $I_{C_2 DC}$.

Now, For Ac.



→ here, $R_E >> r_\pi$ ($\because$ R_E is in $M\Omega$ and r_π is in $k\Omega$).

So. $R_E \| r_\pi \approx r_\pi$

So, R_E is shunted by r_π (dynamic resistance) as $R_E >> r_\pi$.

Now, $V_{o1} = -I_{c_{DC1}} \cdot R_c$. $\qquad \frac{I_c}{V_{BE}} = -g_m$.

$\therefore V_{o1} = -g_m R_c \cdot (V_{BE1})$

$\therefore V_{o1} = -g_m R_c \left(\frac{v_{in}}{2}\right)$ $\qquad$ ($\because V_{BE1} = \frac{V_{in}}{2}$ see fig.).

similiary

$\therefore$ $V_{o2} = -g_m R_c \left(-\frac{V_{in}}{2}\right)$ $\qquad$ ($\because V_{BE_2} = -\frac{V_{in}}{2}$).

$\therefore V_o = V_{o1} - V_{o2}$

$= -g_m R_c \left(\frac{V_{in}}{2} - \left(-\frac{V_{in}}{2}\right)\right)$

$\therefore \boxed{V_o = -g_m R_c \, V_{in}}$

So, $\boxed{A_v = \frac{V_o}{V_{in}} = -g_m R_c.} = A_d$ ← gain of diff ampr

*→ CE amplifier suffers from all common problem. (Noise, drift etc.)

→ Diff. Amplifier eliminates such kinds of all these problem.

→ CE amplifier practically never used.

NOTE:

→ Differential Amplifier is a Basic Building ✓ Block of Analog IC designe.

→ Need for voltage divider and coupling ✓ capacitor to bias the BJT is eliminated in differential amplifier with -ve supply.

→ The need for the Bypass capacitor is ✓ eliminated in a differential amplifier with two symmetrical structure (OR) with a two symmetrical circuit.

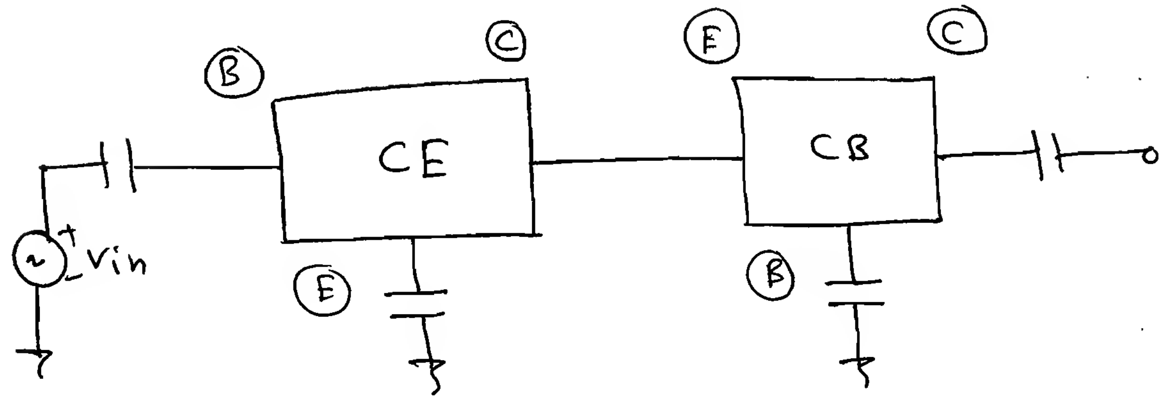
→ O/P capacitor is eliminated by differential ✓ measurement.

→ The input capacitor is eliminated by ✓ Negative supply.

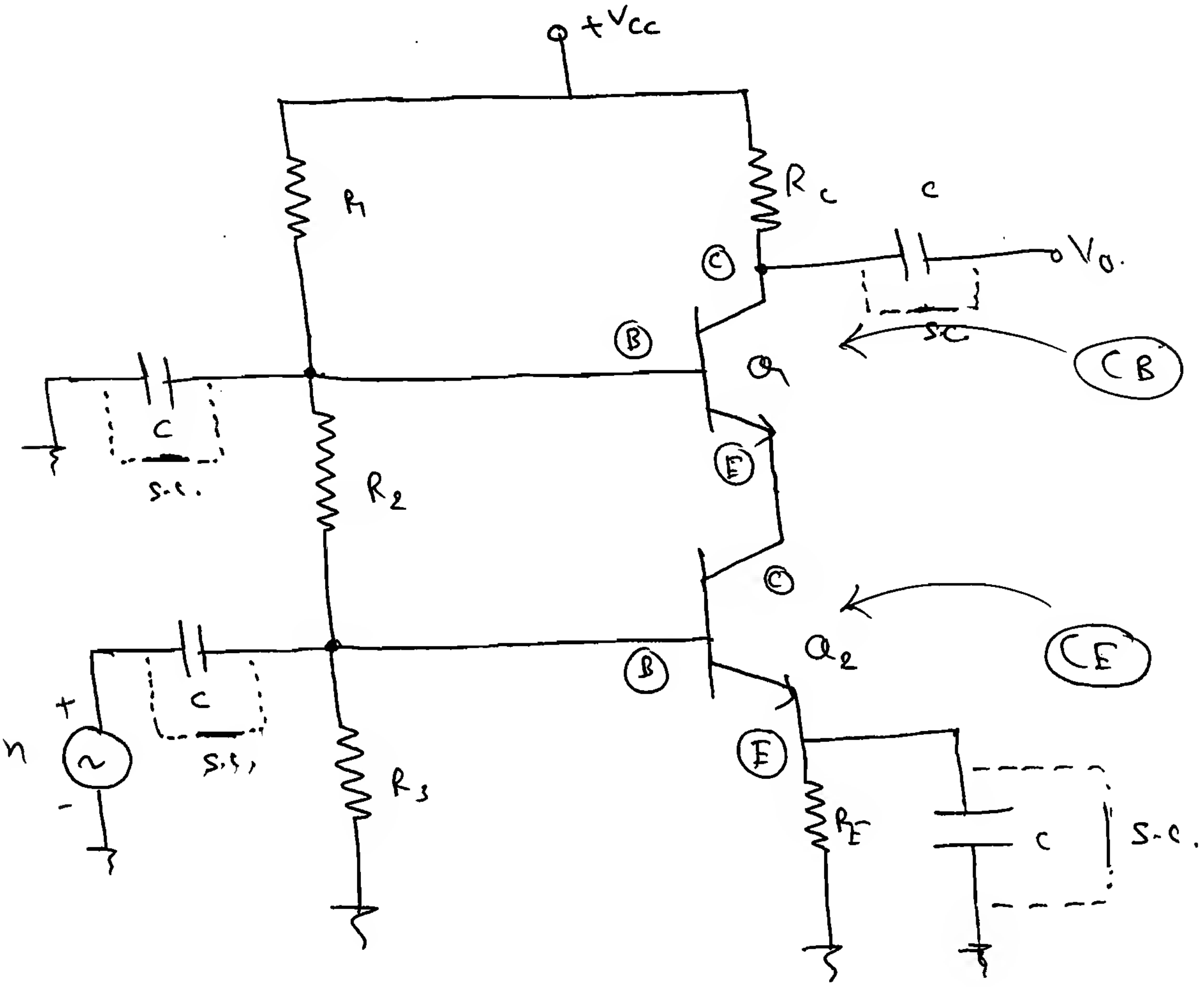
→ Capacitor has to be eliminated because it takes more space in circuites and the soln of this problem is differential amplifier.

☆ Cascode Amplifier [wide Band structer]

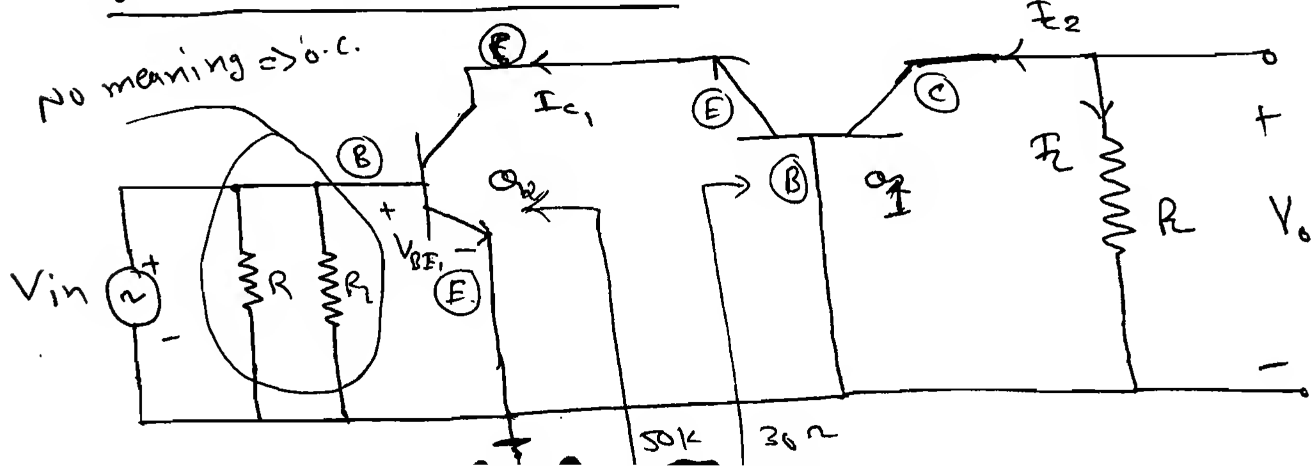
see sujal's VLSI note.



→



→ for AC picture S.C. C



$\rightarrow \quad g_m = \dfrac{I_{C(AC)}}{V_{BE(AC)}}$.

$I_E = -I_C$.

$\therefore \quad V_{in} = V_{BE(AC)}$.

$\therefore \quad V_o = I_C R_C$

$V_o = -I_C R_C = -I_{C(AC)} R_C$

$\therefore \quad A_V = \dfrac{V_o}{V_{in}} = \dfrac{-I_{C(AC)} \cdot R_C}{V_{BE(AC)}}$.

$\therefore \quad \boxed{A_V = -g_m \cdot R_C.}$

$\rightarrow \quad B_W = \dfrac{1}{RC}$, Time constant = RC.

$C_{eq} \uparrow$ (miller effect)

$R \downarrow$ (Cross) impedence mismatch.

→ one way to improve BW is by giving -ve feedback but -ve feedback reduced the gain.

→ But in Casecode Amplifier BW is increased without Reducing gain.

→ Casecode: connection of C or CE to the B or CB is called

→ Casecode: O/P of one stage is connected to the I/P of another stage

* Advantages:

→ Wider BW.

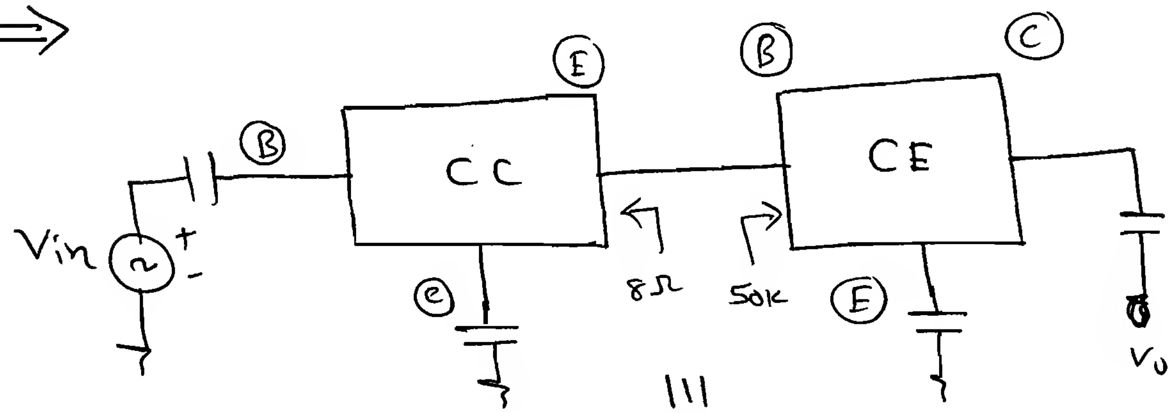
→ The overall transconduction of Casecode Amp = the larger transconduction of Common Emitter amplifier.

→ Large output Impedence.

* Common Collector With Common Emitter.

[wideBand Structure].

⇒



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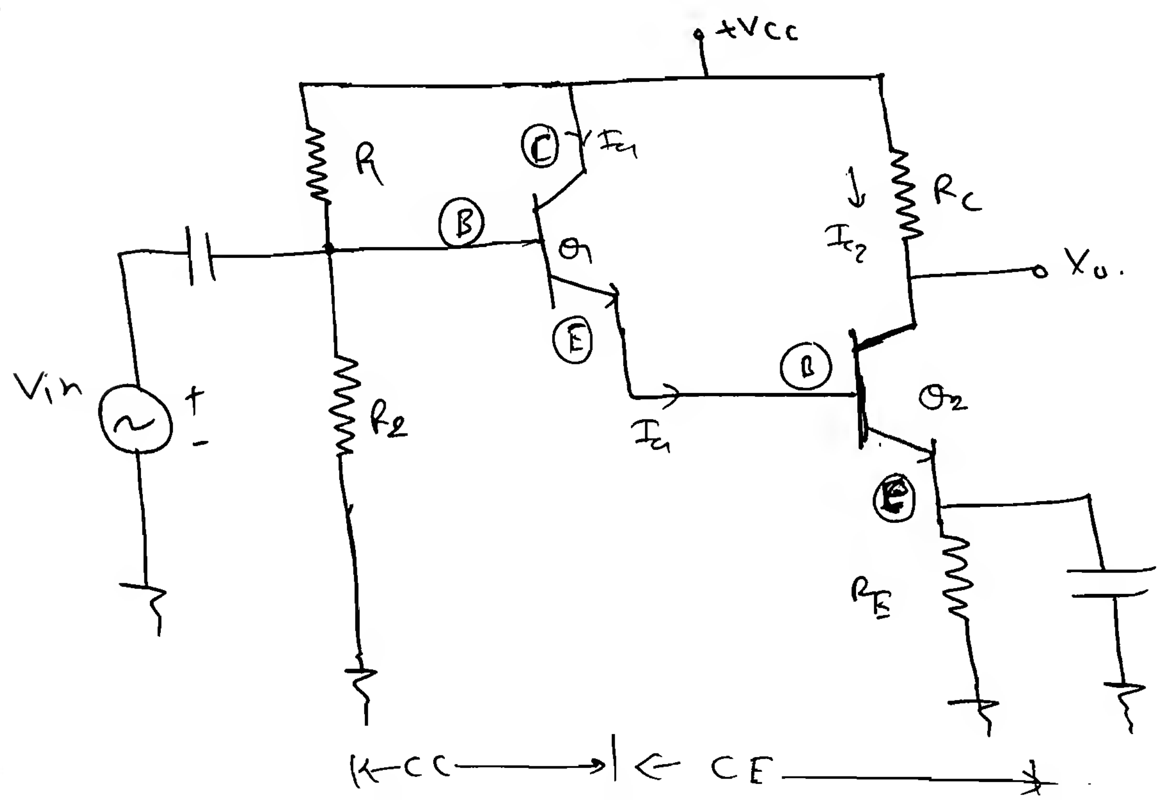
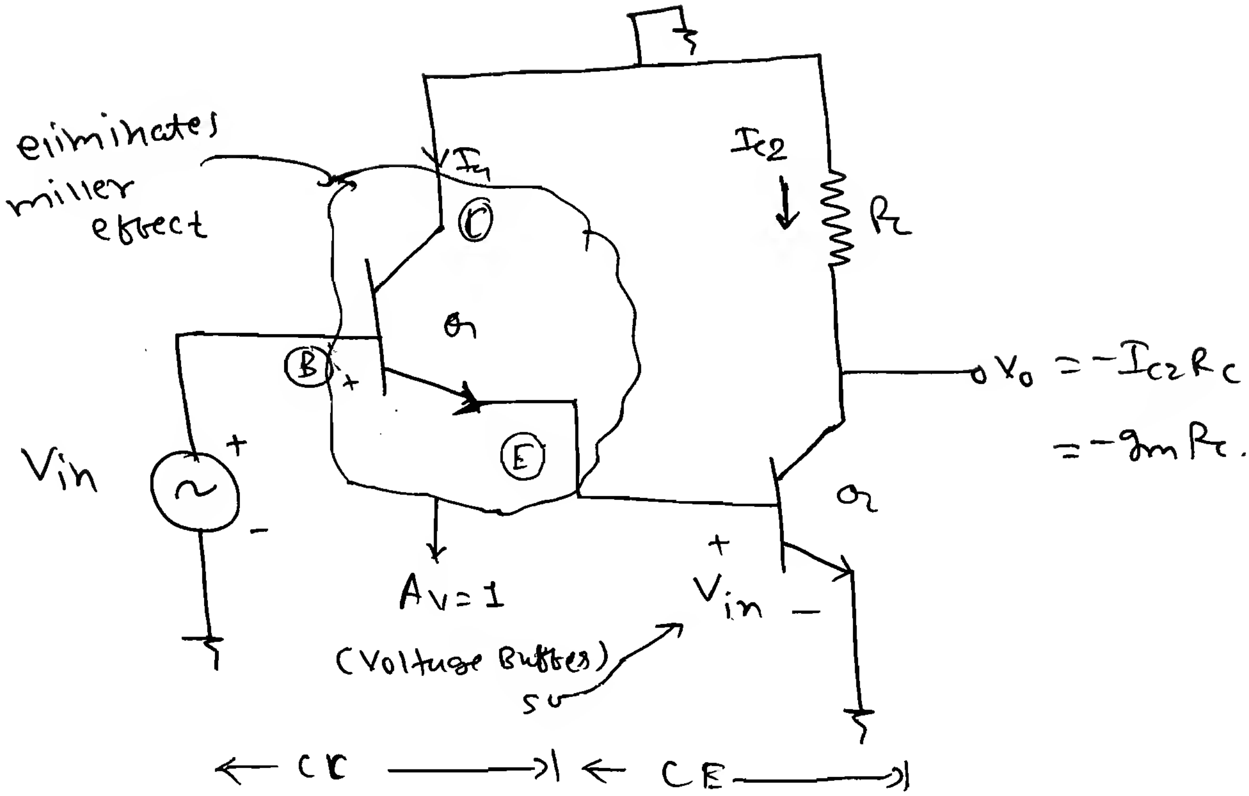


→ AC picture:



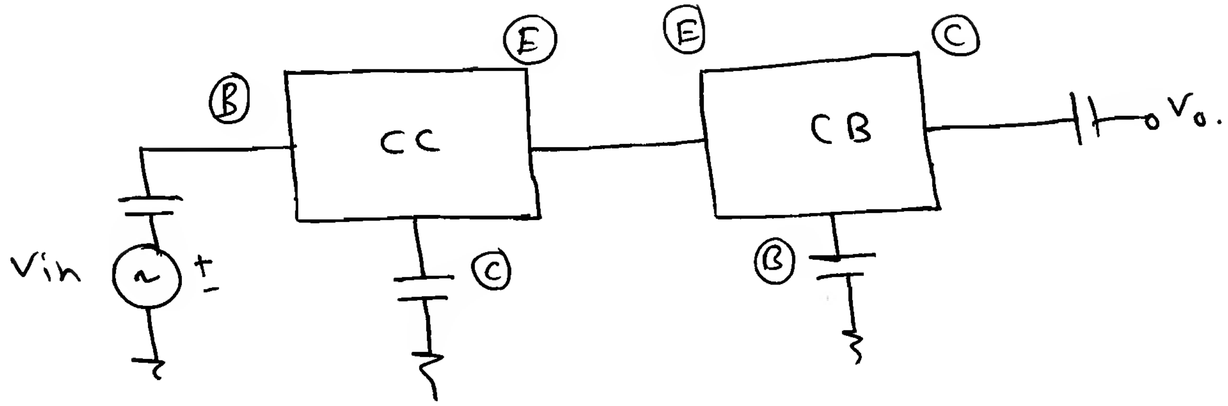
→ Current Buffer at o/p (A_I = 1) (or)
Voltage Buffer at i/p ($A_V = 1$) is put inorder to avoide miller's effect.

→ The overall transconductance is g_m and voltage gain,

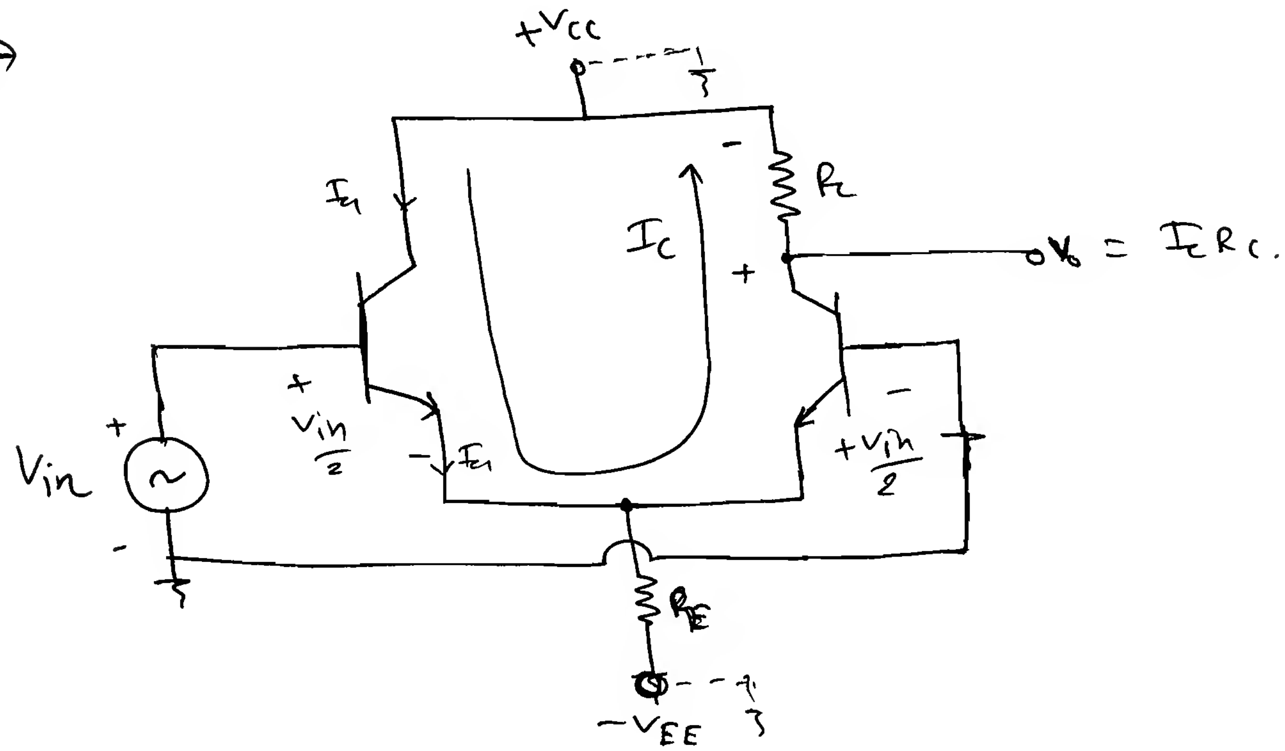
$$\therefore \boxed{A_V = -g_m R_C}$$

* Common Collector with Common Base:

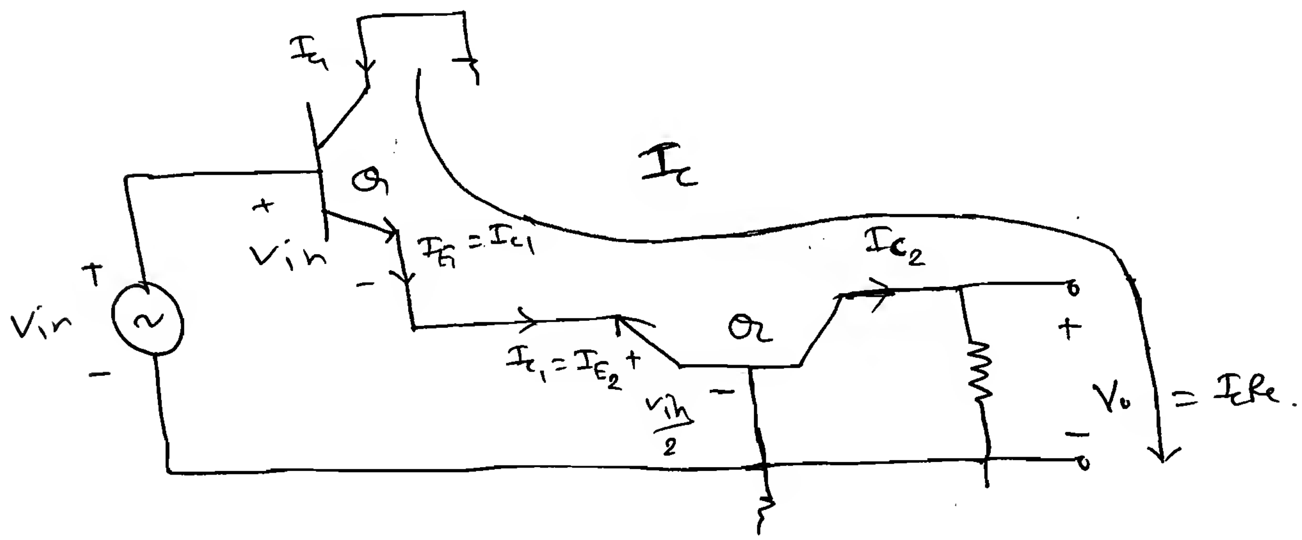
→



→



→



→ $V_o = I_c R_c$

$$\therefore \quad g_m = \frac{I_{C(AC)}}{V_{BE(AC)}} \quad , \quad V_{BE} = \frac{V_{in}}{2}.$$

$$\therefore \quad g_m = \frac{I_{C(AC)}}{V_{in}/2}$$

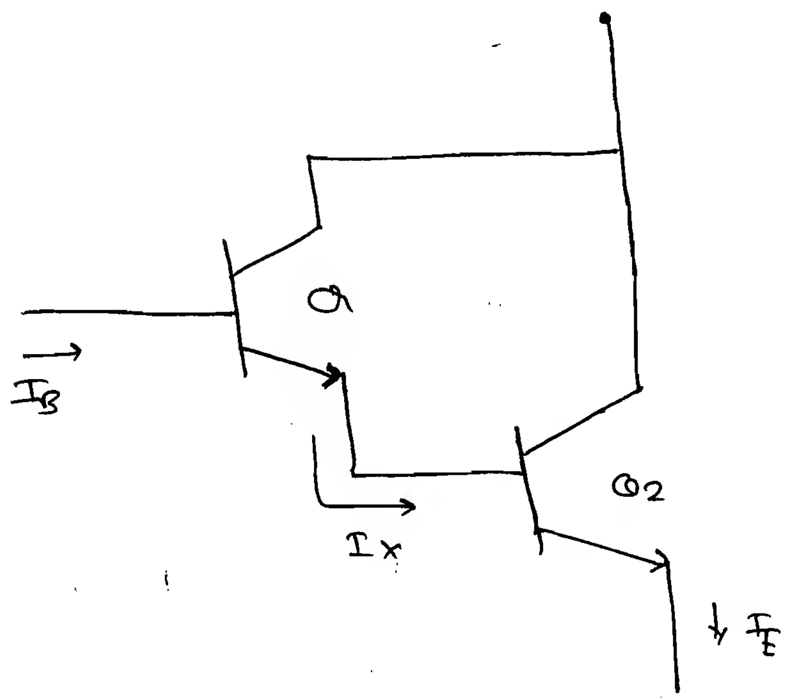
$$\therefore \quad \frac{g_m}{2} = \frac{I_{C(AC)}}{V_{in}}.$$

$$\therefore \quad A_V = \frac{V_o}{V_{in}} = \frac{I_C \cdot R_C}{V_{in}}.$$

$$\therefore \quad \boxed{A_V = + \frac{g_m}{2} \cdot R_C.}$$

☆ Darligton Transistor Pair:

→ Advantges: :- High current gain, High i/p impedence.



→ $I_E = (\beta+1)\, I_x$.

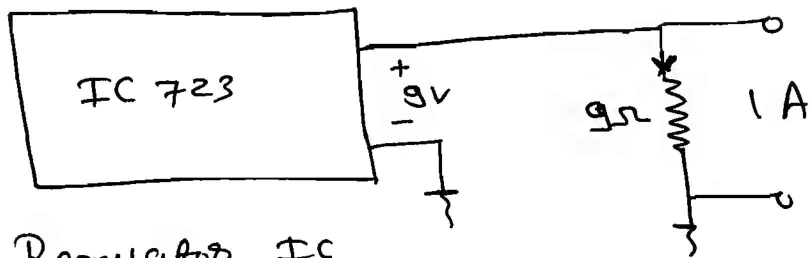
But $I_x = (\beta+1)\, I_B$.

So, $\boxed{I_E = (\beta+1)^2\, I_B}$.

→ To deal with worst load, darligton pair used.

let, 9Ω load

⇒



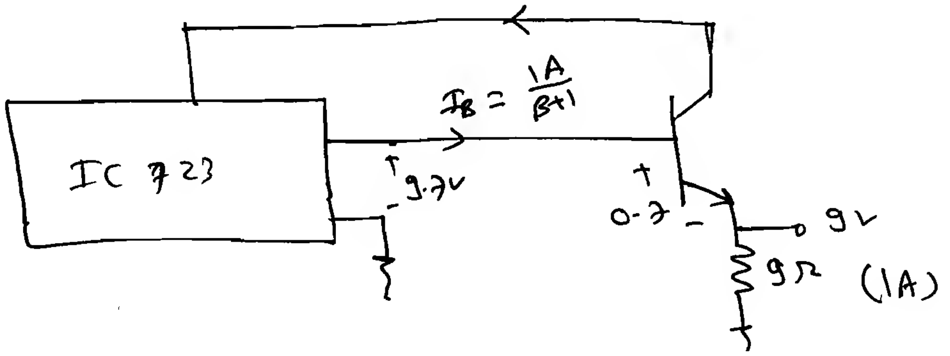
Regulator IC

→ Here, Voltage at IC o/p is, 9v and load is connected which is 9Ω. So, current flowing through the ckt is 1A which is too high for the IC723. because IC723 can handle maximum current upto 100mA. and IC gets burn.

→ Now, Put transistor as shown in figure.

let

$\boxed{\beta = 10}$

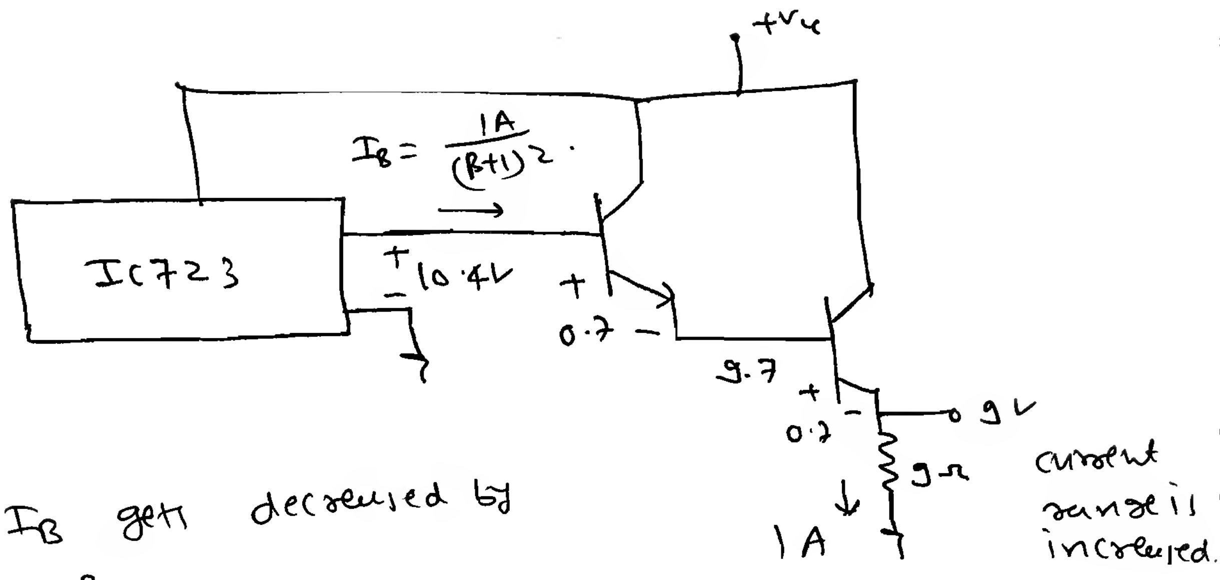


$I_B = \frac{1}{10x}$

$\boxed{I_B = 100mA}$

which is also high

Now, use Darlington pair of Transistor.



→ I_B gets decreased by $(\beta+1)^2$

$\therefore I_B = \frac{1}{100}$

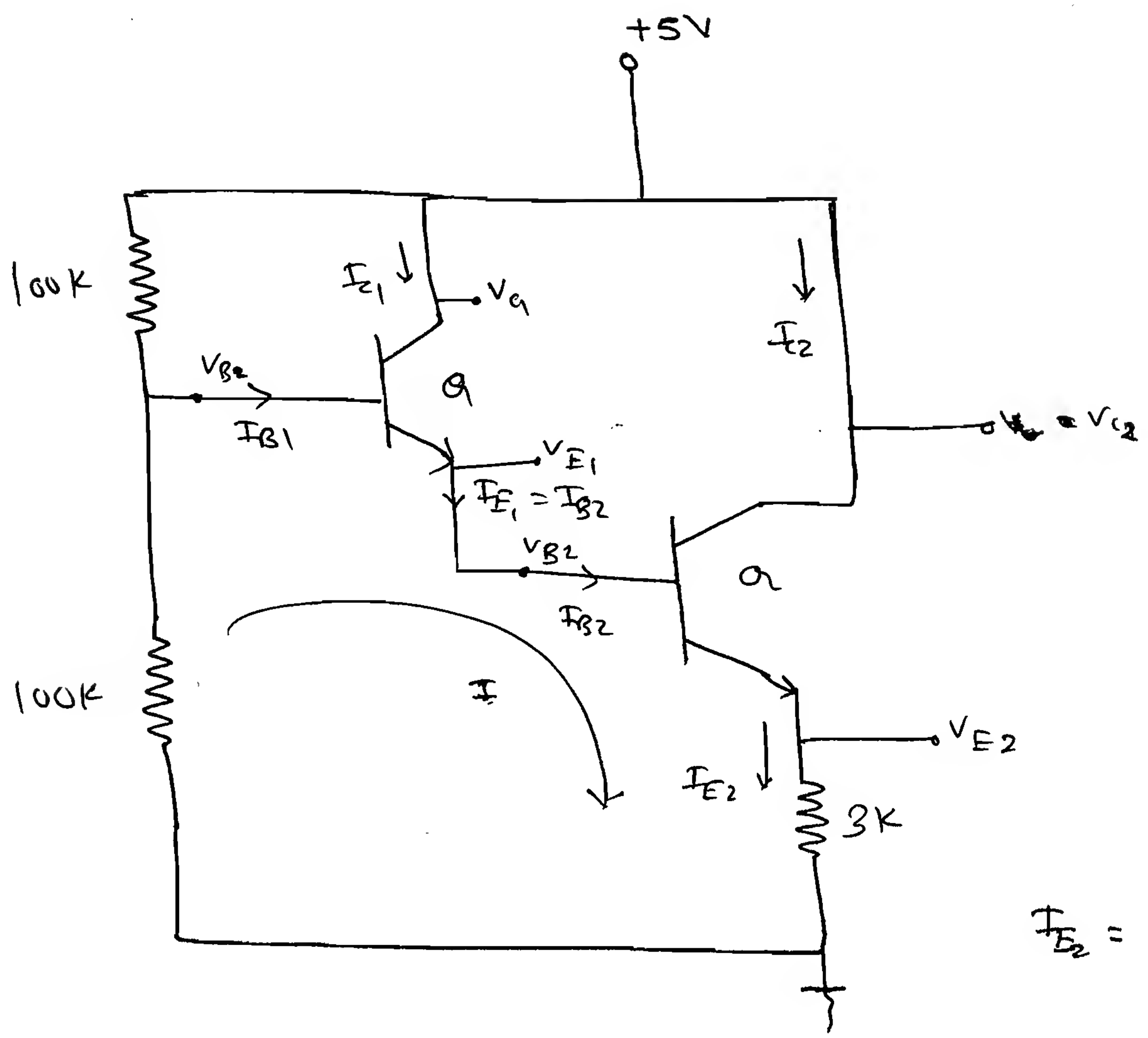
$\therefore \boxed{I_B = 10\,mA}$.

→ Now, IC can driven by darlington pair of transistor.

→ Now, Inorder to produce 9V across the 9Ω Load 1 A current is available because of darlington pair even if current flowing through IC is 10mA. The required current gain (10mA to 1A) is provided by darlington pair.

Ex-1 Calculate node Voltage and Branch current.

take $\beta = 75$.



$$I_{E_2} = \frac{I_{B2}}{\beta+1}$$

$\rightarrow$ $V_{th} = \frac{100}{200} \times 5 = 2.5V.$, $R_{th} = 50K$

$\therefore$ $V_{th} - I_{B1} R_{th} - V_{BE} - V_{BE} - I_{E2} R_{E2} = 0.$

$\therefore$ Now, $I_{E_2} = \frac{I_{B2}}{(\beta+1)}.$

But $I_{B2} = \frac{I_{B1}}{(\beta+1)}.$

So, $I_{E_2} = \frac{I_{B2}}{(\beta+1)^2}.$

$$\therefore \quad I_{E2} = \frac{V_{th} - 2V_{BE}}{R_E + \frac{R_{th}}{(\beta+1)^2}}.$$

$$\therefore I_{E_2} = \frac{2.5 - 1.4}{3000 + \frac{50000}{(76)^2}}$$

$$\therefore \boxed{I_{E2} = 0.366\,mA}$$

$$\therefore I_{C2} = \frac{\beta}{\beta+1} \times I_{E_2}$$

$$\therefore I_{C2} = \frac{75}{76} \times 0.366$$

$$\boxed{I_{C2} = 0.361\,mA}$$

$$\therefore I_{B2} = I_{E_2} - I_{C2}$$

$$\therefore \boxed{I_{B2} = 4.815\,\mu A}$$

$$\therefore \boxed{I_{E1} = 4.815\,\mu A}$$

$$\therefore I_{C1} = \frac{75}{76} \times 4.815$$

$$\therefore \boxed{I_{C1} = 4.75\,\mu A.}$$

$$\therefore \boxed{I_{B1} = 63.35\,nA.}$$

$$\therefore V_{B1} = V_{th} - I_{B1} \cdot R_{th}$$

$$\therefore V_{B1} = 2.5 - (63.35 \times 10^{-9} \times 50 \times 10^{3}).$$

$$V_{B1} = 2.5 - 0.003167$$

$$\therefore \boxed{V_{B1} = 2.496\,V}$$

$$V_{E1} = V_{B1} - 0.7$$

$$\therefore \boxed{V_{E1} = 1.796\,V}$$

$$\boxed{V_{C1} = 5V}$$

$$\boxed{V_{C2} = 5V}$$

$\therefore \quad V_{E2} = I_{E2} \times R_E$

$\therefore V_{E2} = 0.36 \times (3).$

$\therefore \boxed{V_{E2} = 1.098V}.$

$\therefore \quad V_{CE1} = V_{C1} - V_{E1}$

$= 5 - 1.796$

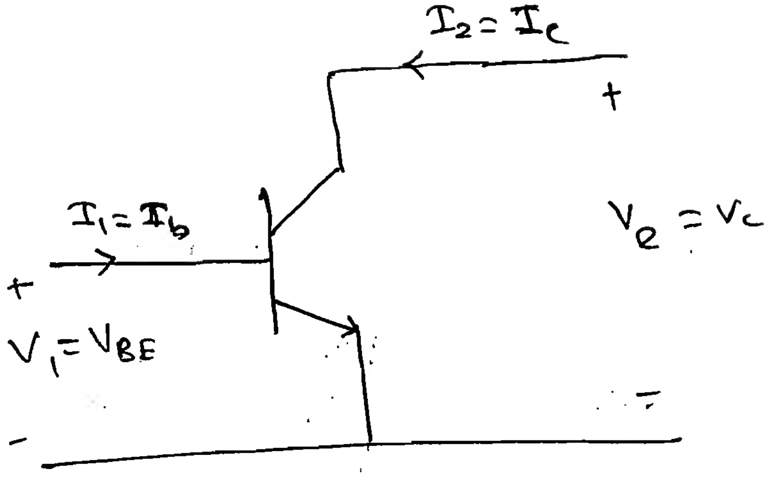
$\therefore \boxed{V_{CE1} = 3.204}$

$\therefore \quad V_{CE2} = V_{CE1} + 0.7$

$\therefore V_{CE2} = 3.204 + 0.7$

$\therefore \boxed{V_{CE2} = 3.914V}$

☆ Hybrid Model:

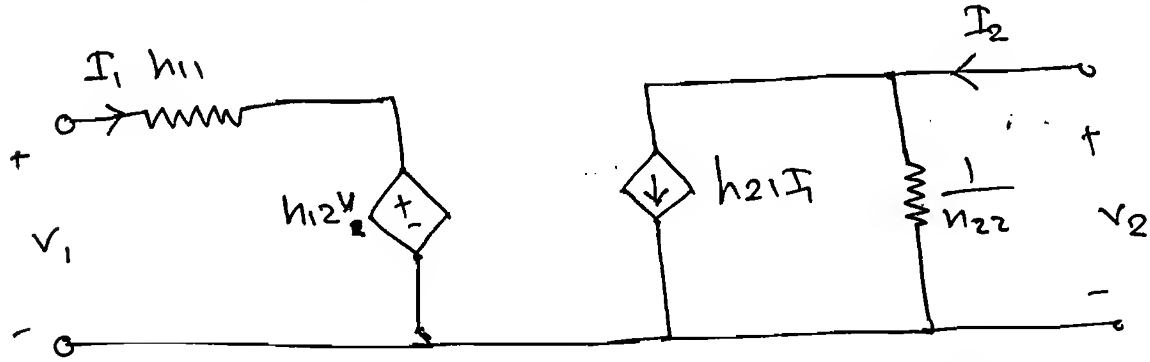


→ $V_1 = h_{11} I_1 + h_{12} V_2$ (KVL, thevenian)

$I_2 = h_{21} I_1 + h_{22} V_2$. (KCL, Norton).

let, $V_1 = V_{BE}$, $V_2 = V_{CE}$
$I_1 = I_B$, $I_2 = I_c$.

$h_{11} = h_{ie}$, $h_{12} = h_{re}$
$h_{21} = h_{fe}$, $h_{22} = h_{oe}$



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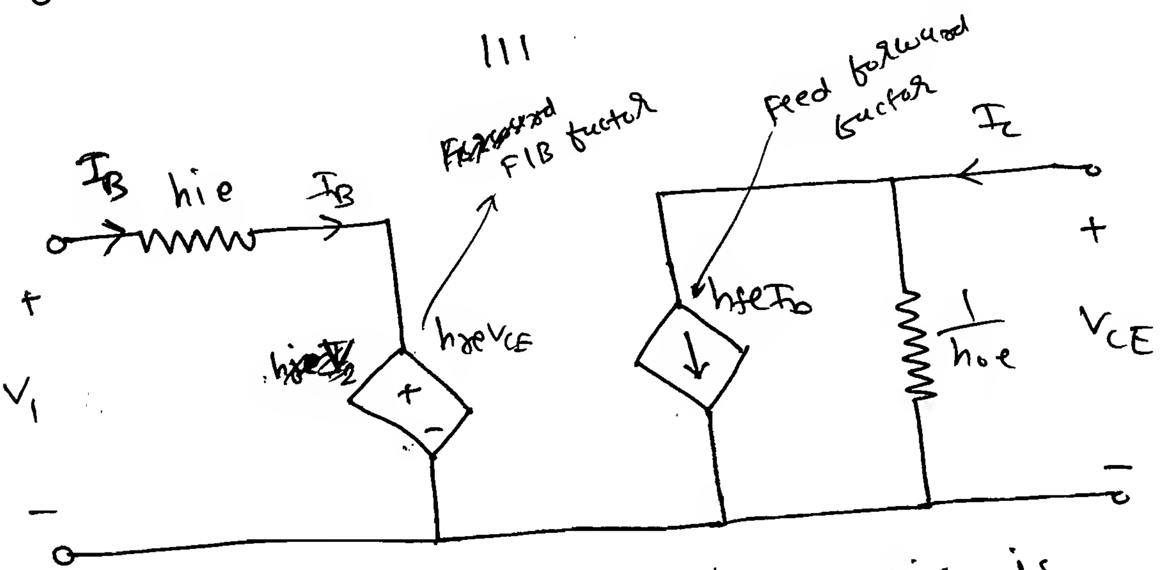


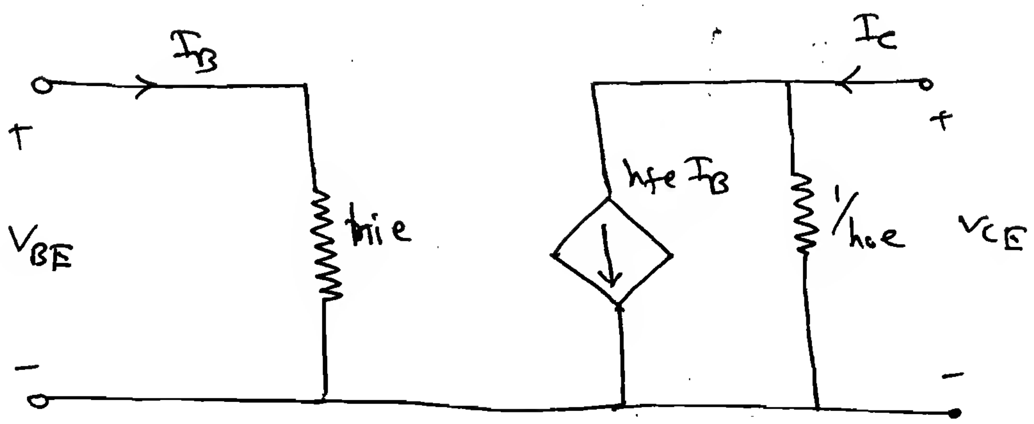
Where, $h_{11} = h_{ie}$, $h_{12} = h_{re}$
$h_{21} = h_{fe}$, $h_{22} = h_{oe}$.

This is H model of Transistor.

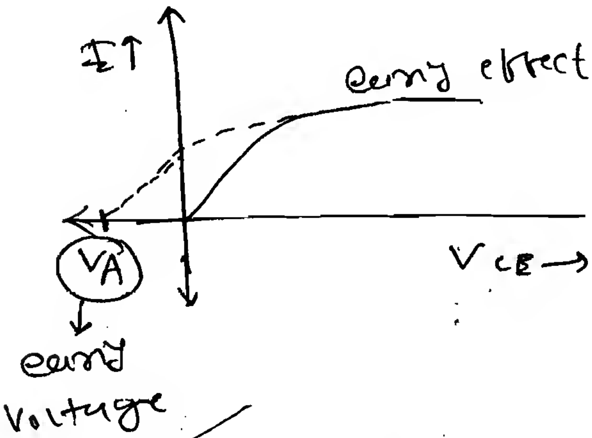
2!

→ as the $h_{re} = 10^{-12}$ and $h_{fe} = 100$.

we can negate h_{re} and the ckt will be.



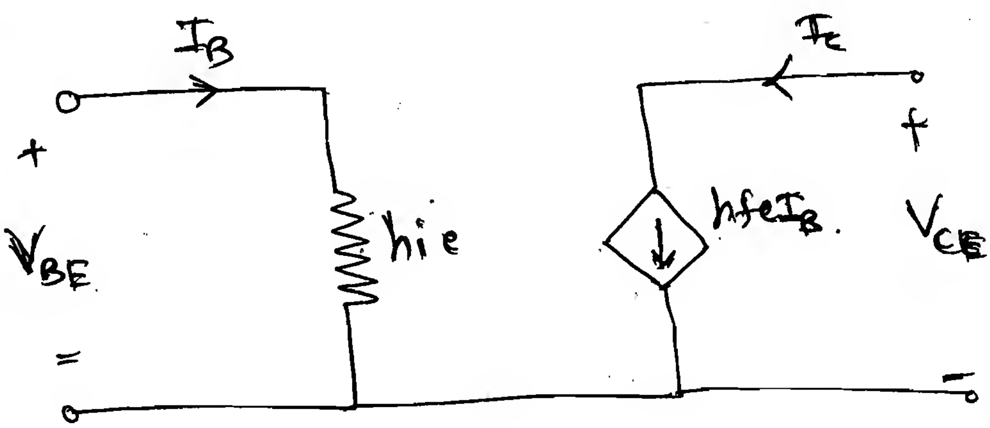
Now, $h_{oe} = \dfrac{I_c}{V_{CE}}$.



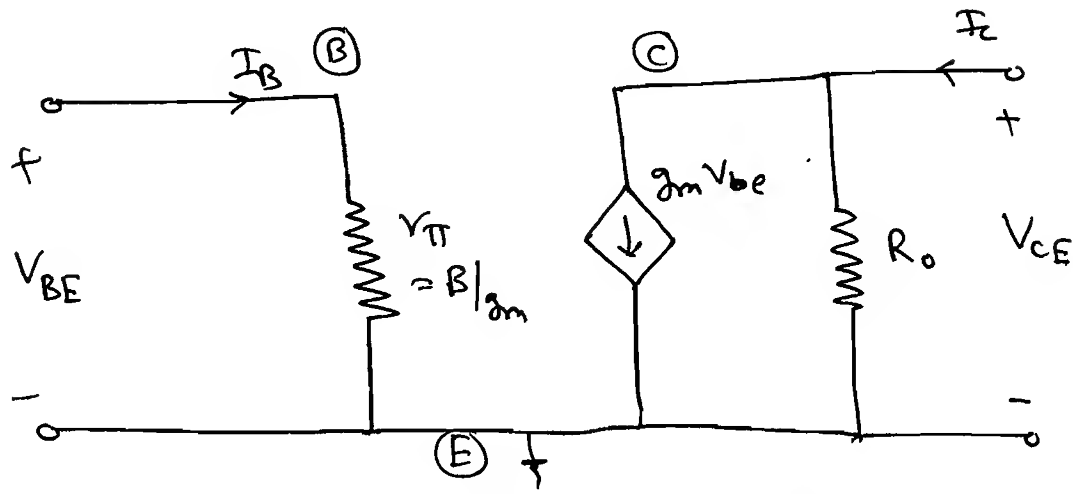
$\dfrac{1}{R_o} = \dfrac{I_c}{V_{CE}} = \dfrac{1}{\text{slope}}$

$\boxed{h_{oe} = 0.}$

so final H-model is as below:



* π model is seeing from base.



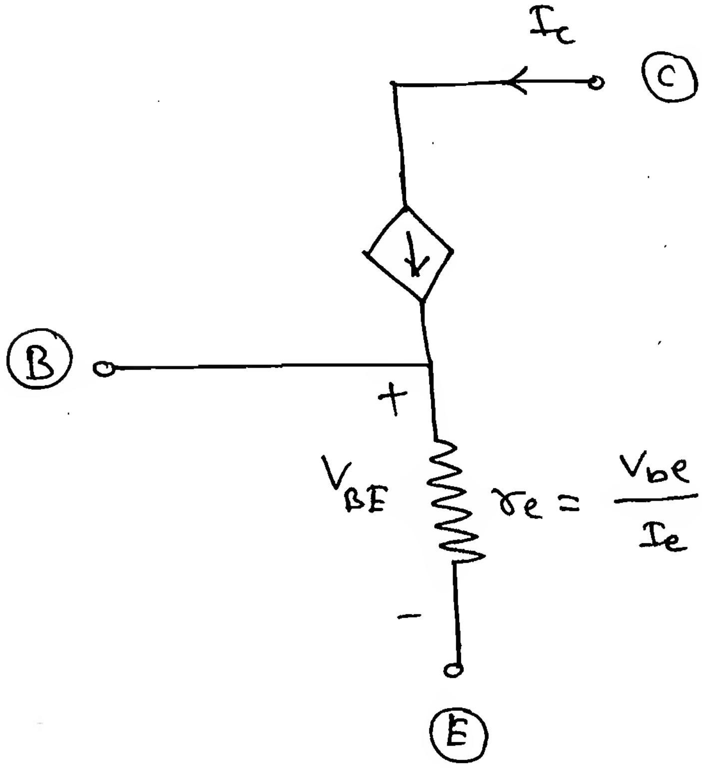
$\Rightarrow$ 1) $r_\pi = h_{ie} = \beta / g_m$.

2) $h_{fe} = \beta$

3) $R_o = \dfrac{1}{h_{oe}} = \dfrac{V_A}{I_{c_{DC}}}$.

$$\boxed{g_m = \frac{h_{fe}}{h_{ie}}}$$

* T- Model:



$r_e = \dfrac{V_{be}}{I_e}$.

gain $\dfrac{V_o}{V_{in}} = -g_m R_c$.

$$\therefore \boxed{A = -\frac{h_{fe}}{h_{ie}} \cdot R_c}$$

← T model is seeing through emitter.

⇓

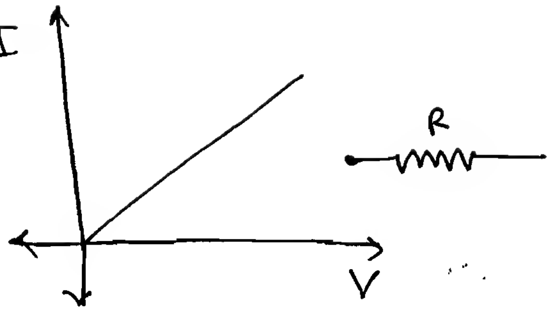
to find operating point.

$\therefore r_e = \dfrac{V_{be}}{I_e} = \dfrac{V_{be}}{I_c}$.

$\therefore \boxed{r_e = 1/g_m}$

21

*



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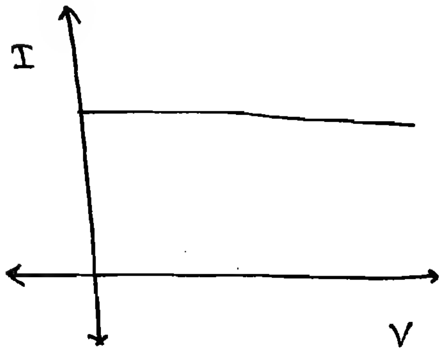
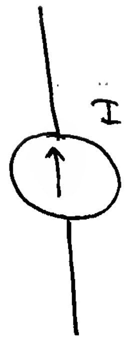
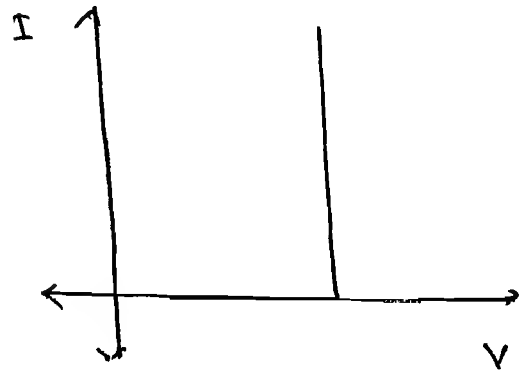
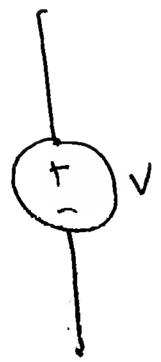




current source.

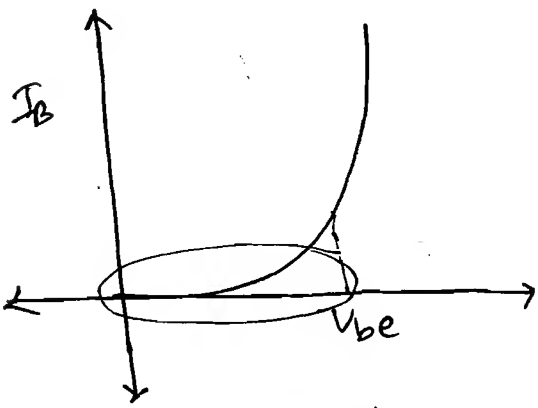
*

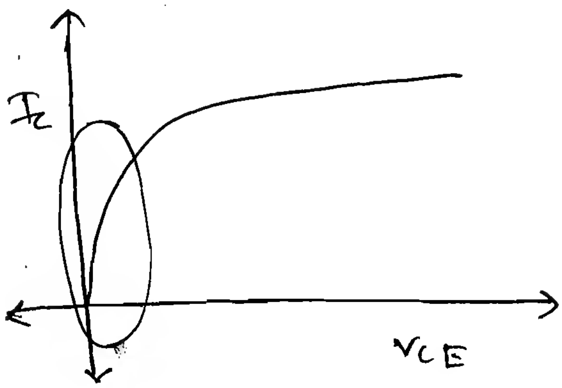




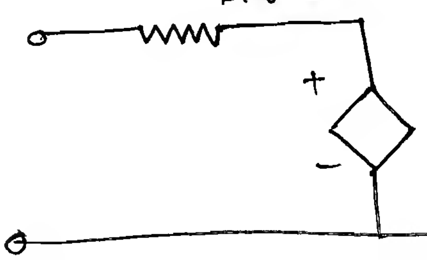
Voltage Source.

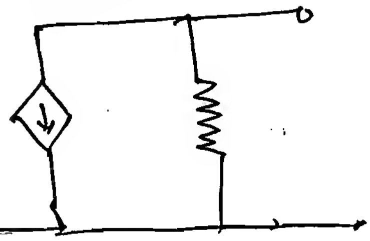
*





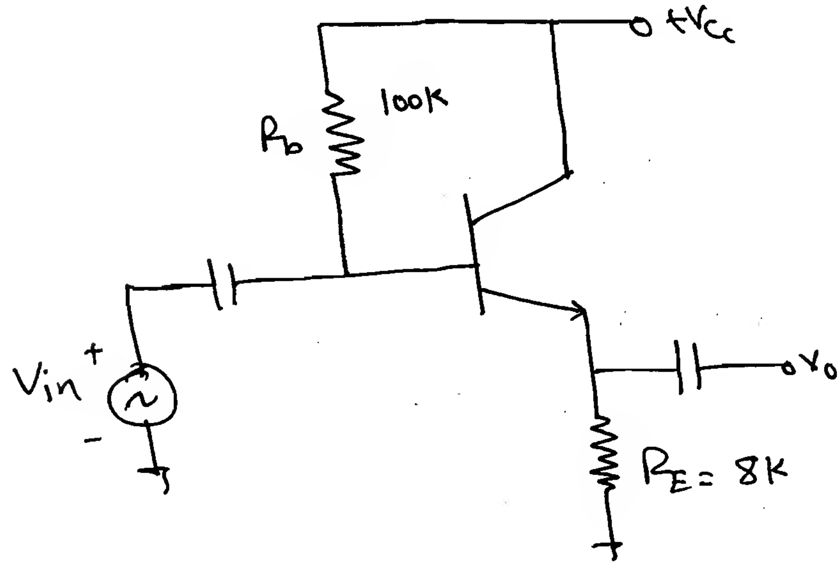
Thevinin ~~Norton~~ + Norton.



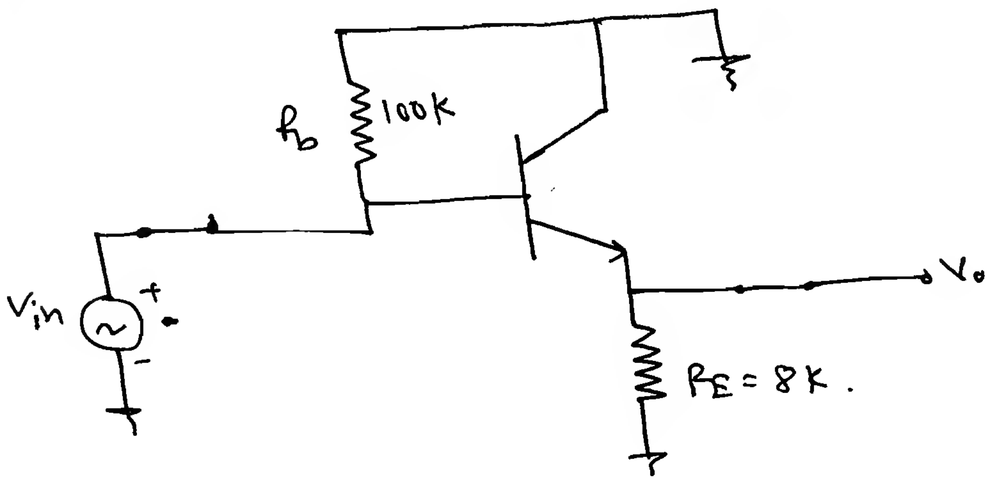


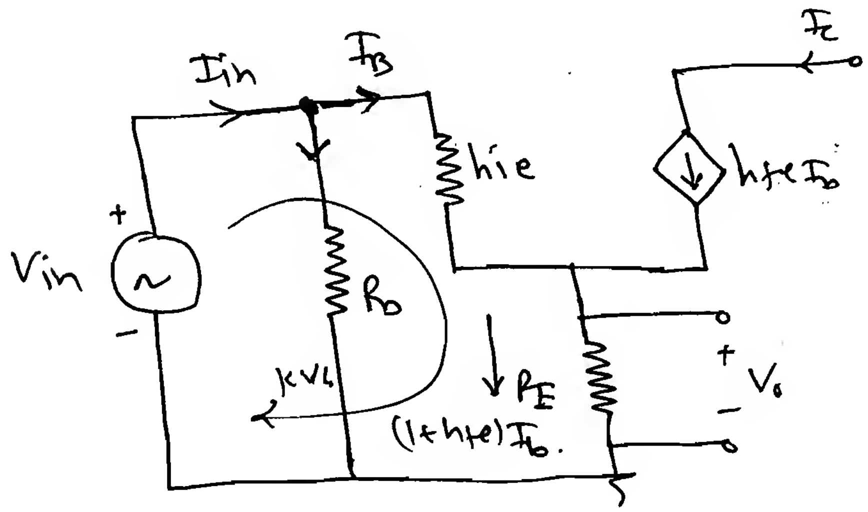
Ex-1 For emitter follower circuit given calculate input impedence, o/p impedence and voltage gain. $h_{ie} = 1K$, $h_{fe} = 100$.

Ans:



→ Ac picture:





F.d

$V_o = (1+h_{fe}) I_B \cdot R_E.$

$\therefore \; V_{in} - I_b h_{ie} - (1+h_{fe}) I_b R_E = 0.$

$\therefore \; V_{in} = I_b [\, h_{ie} + R_E (1+h_{fe}) \,].$

$\therefore$ Voltage gain $= A_v = \dfrac{V_o}{V_{in}}.$

$$\therefore \; A_v = \frac{R_E (1+h_{fe})}{h_{ie} + R_E (1+h_{fe})}.$$

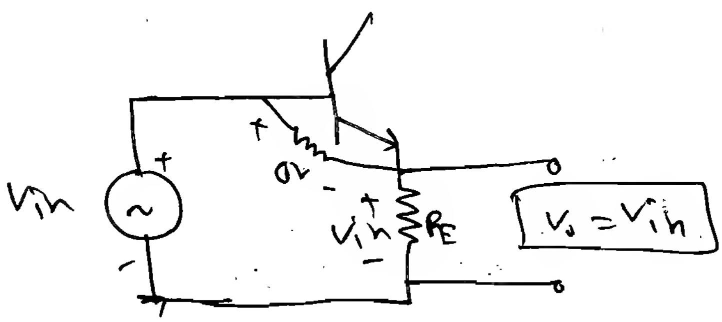
$$\therefore \; A_v = \frac{8000\,(1+100)}{1000 + 8000\,(1+100)}.$$

$\therefore \; \boxed{A_v = 0.99876.}$

We can negate h_{ie} at the begining and

$$\therefore \; A_v = \frac{R_E (1+h_{fe})}{R_E (1+h_{fe})}$$

$\boxed{A_v \approx 1}$ so, emitter follower



$\therefore \; Z_{in} = \dfrac{V_{in}}{I_{in}}.$

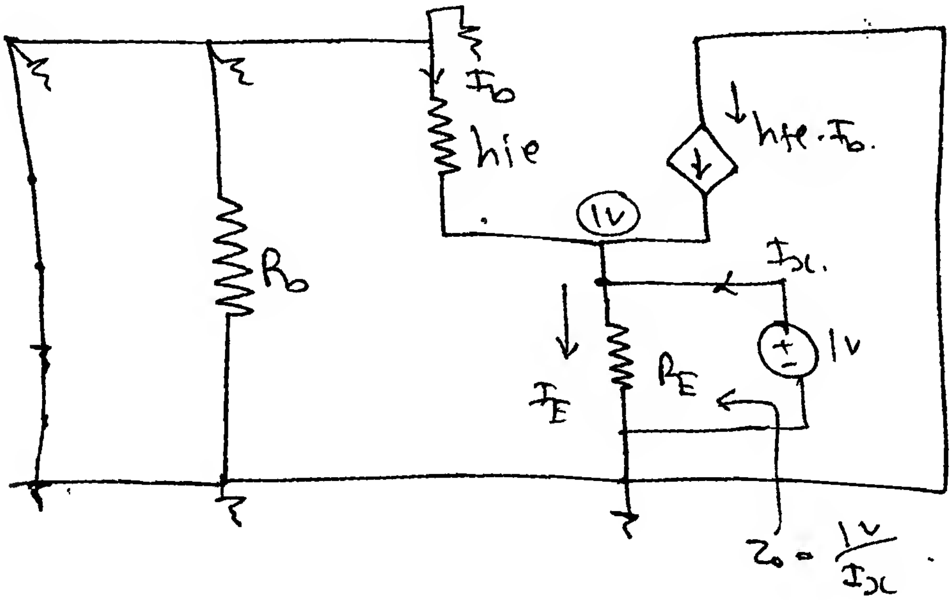
$\therefore \; I_{in} = I_b + \dfrac{V_{in}}{R_b}.$

$$\therefore \quad I_{in} = \frac{V_{in}}{R_b} + \frac{V_{in}}{h_{ie} + (1+h_{fe}) R_E} .$$

$$\therefore \quad \frac{V_{in}}{I_{in}} = \frac{1}{\frac{1}{R_b} + \frac{1}{[h_{ie} + (1+h_{fe})R_E)]}}$$

$$\therefore \quad \boxed{Z_{in} = R_b \parallel [\, h_{ie} + (1+h_{fe}) R_E)].}$$

→ Now, finding o/p impedence.



KCL

$$\therefore \quad I_b + I_x + I_c = I_E .$$

$$\therefore \quad \frac{0 - 1V}{h_{ie}} + I_x + h_{fe} \cdot \left(\frac{0-1}{h_{ie}}\right) = \cancel{(1+h_{fe}) I_b} \cdot \frac{1V}{R_E} .$$

$$\therefore \quad (1+h_{fe}) \left(-\frac{1}{h_{ie}}\right) + I_x = \frac{1}{R_E} .$$

$$\therefore \quad I_x = \frac{1}{R_E} + \frac{1+h_{fe}}{h_{ie}} .$$

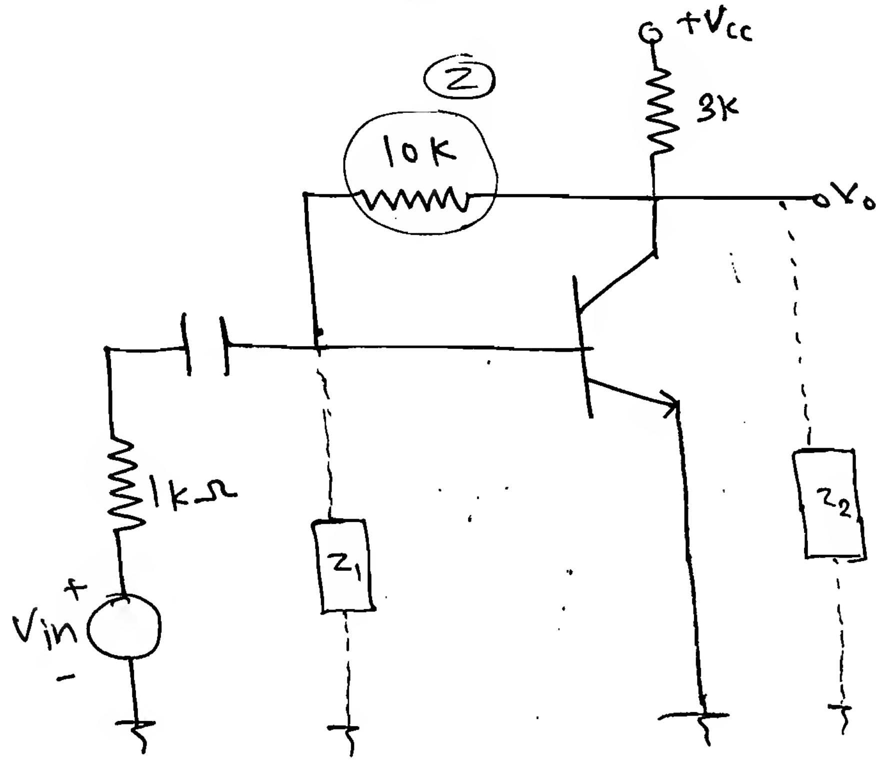
$$\therefore \quad Z_o = \frac{1 \cdot V}{I_x} .$$

$$\therefore \quad Z_o = \frac{1}{\frac{1}{R_E} + \frac{1}{h_{ie}}}$$

$$\therefore \quad \boxed{Z_o = R_E \parallel \frac{h_{ie}}{1+h_{fe}}}$$

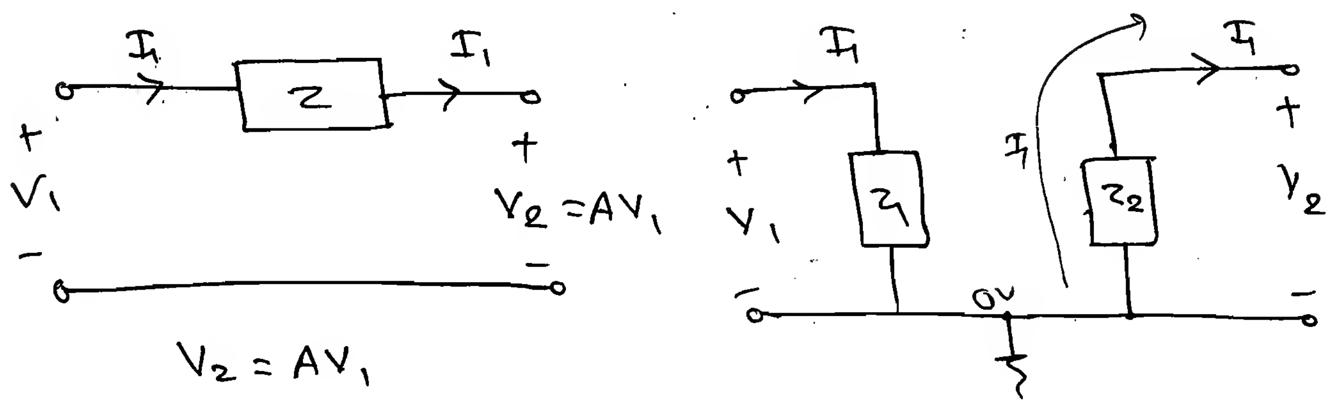
GATE, IES

Ex-2 Using the millers theorem find the voltage gain V_o/V_{in} if $h_{ie} = 1K$, $h_{fe} = 100$.



Ans:

* **Miller's theorem:**



$$V_2 = AV_1$$

$$\rightarrow \quad I_1 = \frac{V_1 - V_2}{Z},$$

$$I_1 = \frac{V_1 - 0}{Z_1}.$$

$$\therefore \quad \frac{V_1 - V_2}{Z} = \frac{V_1 - 0}{Z_1} \qquad \text{but } V_2 = AV_1$$

$$\therefore \quad \frac{V_1 - AV_1}{z} = \frac{V_1}{z_1}.$$

$$\therefore \quad \frac{\cancel{V_1}(1-A)}{z} = \frac{\cancel{V_1}}{z_1}.$$

$$\therefore \quad \boxed{z_1 = \frac{z}{1-A}.}$$

similarly, $$I_1 = \frac{V_1 - V_2}{z} = \frac{0 - V_2}{z_2}.$$

$\therefore$ ~~$V_1(1+A)V_x$~~ But $V_2 = AV_1$

$\Rightarrow V_1 = V_2/A$.

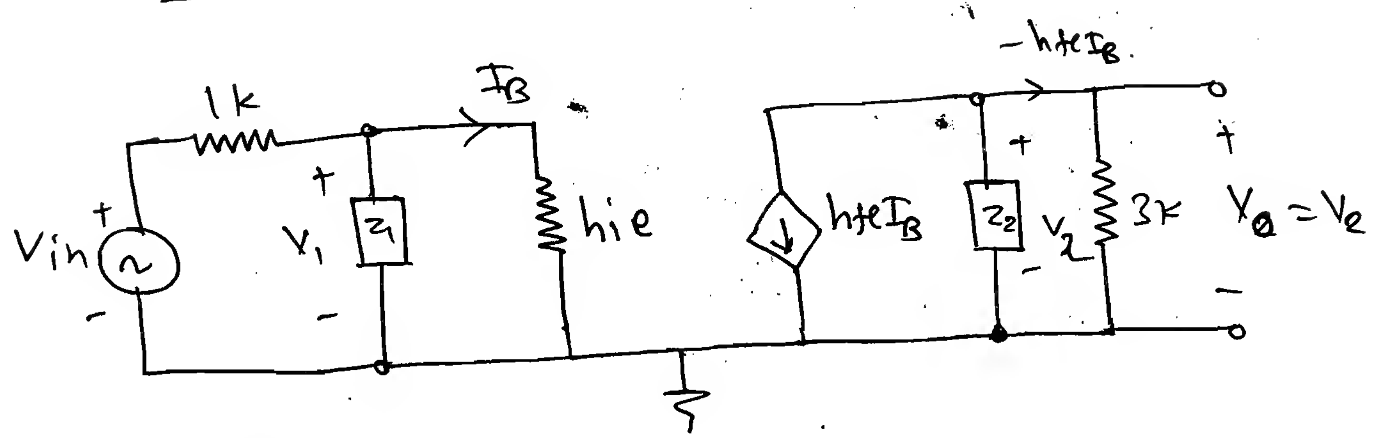
$$\therefore \quad \frac{\frac{V_2}{A} - V_2}{z} = \frac{-V_2}{z_2}.$$

$$\therefore \quad \frac{\cancel{V_2}\left(\frac{1}{A} - 1\right)}{z} = -\frac{\cancel{V_2}}{z_2}$$

$$\therefore \quad z_2 = \frac{z}{1 - 1/A}.$$

$$\therefore \quad \boxed{z_2 = \frac{zA}{A-1}.}$$

Now, <u>Ac picture</u>,



$$z_1 = \frac{10k}{1-A}.$$

$$z_2 = \frac{10k\,A}{A-1}.$$

$$A = \frac{V_2}{V_1} = \frac{V_o}{V_1}$$

$$\boxed{A = V_o/V_1}$$

$$\therefore \quad V_o = -h_{fe} I_B \cdot [3K \parallel Z_2].$$

$$\therefore \quad V_1 = I_B h_{ie}.$$

$$V_1 = I_B (1K).$$

$$\therefore \quad A = \frac{V_o}{V_1} = \frac{-h_{fe}[3K \parallel Z_2]}{h_{ie}}.$$

$$\therefore \quad \cancel{A///} \frac{\cancel{1000}}{\cancel{100}\,\cancel{[1/3000/}}$$

$$\therefore \quad A = -\frac{10\cancel{0}}{10\cancel{0}\cancel{0}} \left[\frac{1}{\frac{1}{3000} + \frac{10KA}{A-1}} \right].$$

$$\therefore +10A = \frac{-1}{\frac{1}{3000} + \frac{1}{\frac{10000A}{A-1}}}.$$

$$\therefore \quad 10A \left[\frac{1}{3000} + \frac{1}{\frac{10000A}{A-1}} \right] = -1.$$

$$\therefore \quad 10A \left[\frac{1}{3000} + \frac{A-1}{10000A} \right] = -1.$$

$$\therefore \quad \frac{10A}{3} + \frac{\cancel{A}(A-1)}{1} = -1000.$$

$$\therefore \quad 10A + 3\cancel{A}(A-1) = -3000\cancel{A}$$

$$\therefore \quad \cancel{3A^2 - 3A + 10A + 3000A = 0}.$$

$$\therefore \quad \cancel{3A^2 + 7A + 3000 = 0}.$$

$$\therefore \quad 13A - 3 = -3000$$

$$13A = -2997$$

$$\therefore \quad \boxed{A = -230.54}$$

$$\therefore z_1 = \frac{10000}{1-A}. \qquad z_2 =$$

$$\therefore z_1 = \frac{10000}{232}.$$

$$\boxed{z_1 = 43.10\,\Omega}$$

$$z_2 = \frac{10k \times A}{A-1} = 10k.$$

$$\therefore \boxed{z_2 = 10K}$$

KCL

$$\therefore \frac{V_{in} - V_1}{1k} = \frac{V_1}{z_1} + \frac{V_1}{1k}.$$

$$\therefore V_1\left[\frac{1}{1000} + \frac{1}{43.2} + \frac{1}{1000}\right] = \frac{V_{in}}{1000}.$$

$$\therefore V_1[2 + 23.20] = V_{in}.$$

$$\therefore \frac{V_1}{V_{in}} = \frac{1}{25.20}$$

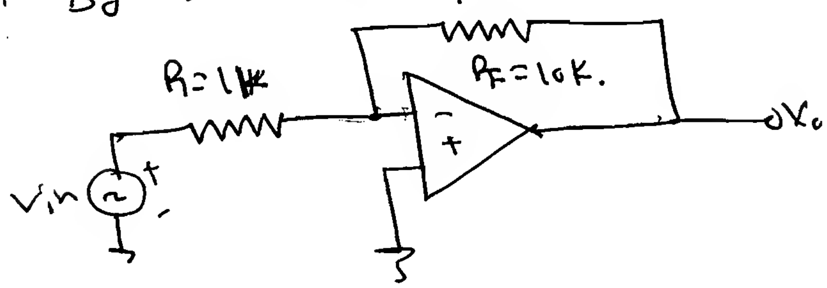
$$\therefore \frac{V_o}{V_{in}} = \frac{V_o}{V_1} \cdot \frac{V_1}{V_{in}}$$

$$= (-232) \times \left(\frac{1}{25.20}\right)$$

$$\therefore A = \frac{V_o}{V_{in}}$$

$$\therefore \boxed{A = -9.2}$$

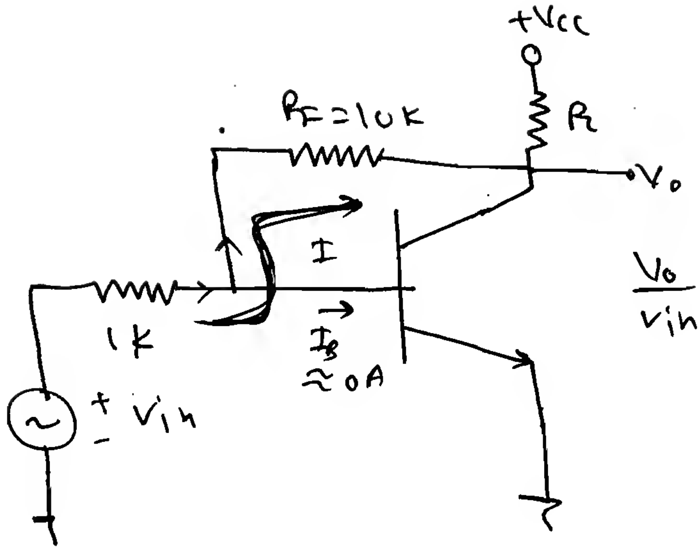
Now, By inspection we can do it easily.



$$\therefore V_o = -R_F/R_1\, V_{in}$$

$$\therefore \frac{V_o}{V_{in}} = A_v \simeq -10.$$

*



$$\frac{V_o}{v_{in}} \approx -10 = A_v.$$